

Chapter SIXTEEN BREEDING



Ninety different strains from Holland were grown out in a Colombian breeding program.

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Chimera, owner of Chimera Seeds.



Cuttings, or clones, taken from the same parent and grown under the same conditions are identical.



Male plants grow flowers that consist of pollen sacks.

Introduction

Chimera is without a doubt one of the most dedicated and knowledgeable people working with cannabis today; he brings a passion to cannabis breeding and research not often seen in the industry. Founder of Chimera Seeds, he has produced some excellent varieties of cannabis including 'C4', 'Frostbite', 'Calizahr' and 'Schnazzeberry'.

Chimera is a well-educated individual, who, for years has tried to understand cannabis and how it functions in the brain. This path has seen him through a B Sc. Neuroscience, and post graduate research in the field of Biotechnology and Plant Sciences. He works on the cutting edge of cannabis research, and will certainly bring many new ideas and technologies to cannabis, over the years to come.

I am very pleased to present Chimera's contribution to this book in the form of this breeding chapter, as he takes the mystery out of breeding and does a great job of simplifying a very complex subject. Thanks, Chimera, for your contributions!

- Jorge Cervantes

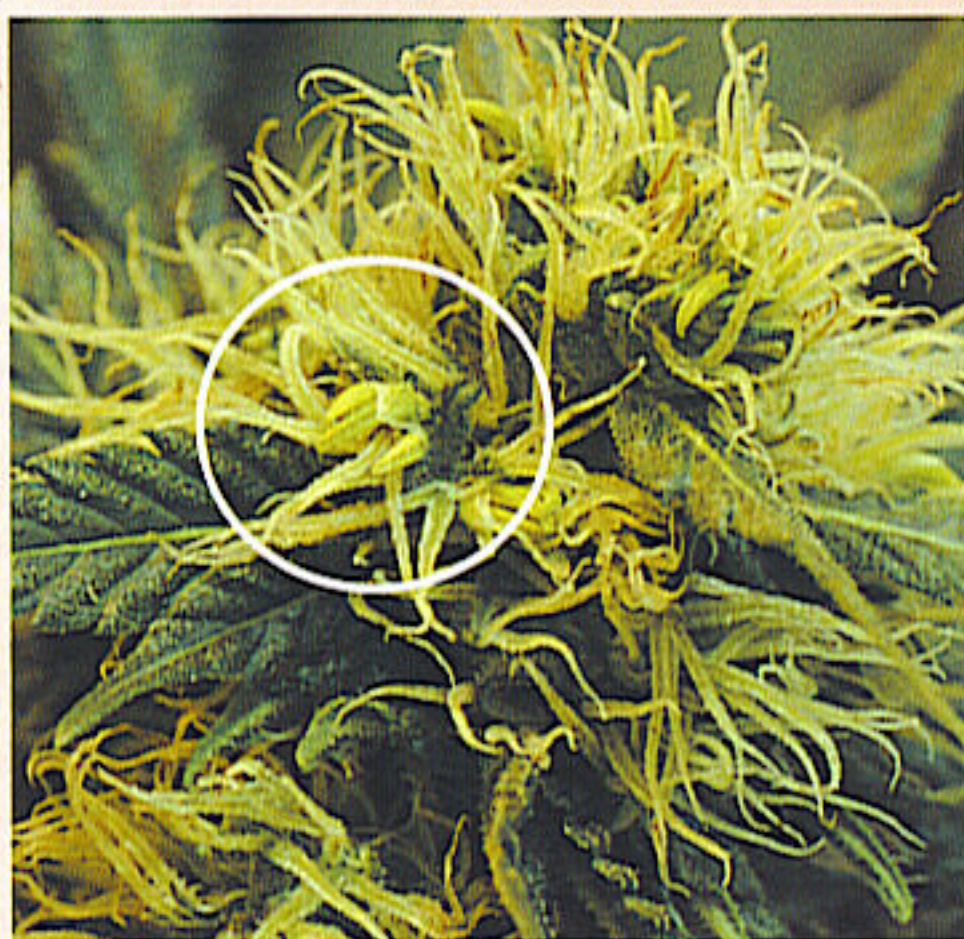
This chapter explains the basic biological processes of sexual propagation in cannabis and the formation of a new generation of seed. Armed with the information in this chapter, any grower will be able to design and begin a rudimentary breeding program and create new generations of seed for future use. These new populations make up a pool of genetic material from which superior individual plants can be selected for production (cloning stock) or for use in breeding programs. It is difficult for small growers to breed better varieties than are available from premium seed companies; however, for the many seed-starved growers who reside in prohibitive societies, making seeds for future use is often a necessity.

Cannabis can be reproduced asexually or sexually. Asexual propagation is more commonly referred to as taking cuttings, or cloning. Branches or growth shoots are removed from chosen donor plants and induced to form roots in a separate medium; these rooted cuttings are then used to plant a uniform crop of genetically identical individuals. Most commercial and

many hobby growers propagate their crops asexually to ensure uniformity in growth, yield, and consistency of product in their crops. By planting gardens of genetically identical cuttings from their favorite pre-selected mother plants, growers are able to maintain an even garden profile, produce a consistent, known quality and quantity from each plant, and expect that all plants will mature at the same time. This ensures the same consistent, quality product from consecutive crops, as long as the same high-quality clones are used for each planting. Gardens propagated solely from clones are the most productive and consistent.

Sexual propagation is the process in which male and female sex cells (gametes) from separate parents unite in the female plant to form what will eventually mature into a new, genetically distinct individual. This process occurs when pollen from a male (staminate) parent unites with an ovule within the ovary of a female flower to create an embryo. This embryo, when mature and fully developed, will become a seed.

Each seed is genetically unique and contains some genes from each of its parent plants. Offspring grown from seed are most often different in some way from each other, just as brothers and sisters share some physical qualities of each of their parents, but are rarely identical to their parents or siblings. Because of this variation in plant traits and characters, breeders are able to use sexual reproduction to their advantage by crossing different individuals within a population or family, or hybridizing unrelated lines and subsequently inbreeding the progeny. This results in a phenomenon known as recombination of traits, and it allows breeders the possibility to recover individuals with a combination of the positive traits of both parental lines, all the while selecting plants that do not express the negative aspects. These selected plant stocks are then used as a basis to develop new and improved varieties.



A single male flower on a predominately female plant will release much pollen.



Female plants grow (white) pistils to attract male pollen.

Distinguishing between male (staminate) and female (pistillate) plants is easy. Male plants are distinguished by the appearance of "pollen sacks," or anthers, that grow from branch unions. Anthers look similar to a cluster of grapes or a collection of miniature lobster claws growing upwards and inverted from the branch union. Males typically begin to produce these flowers one to four weeks before the females of the same variety, and often bolt, or stretch, when they enter their floral development stage. Females can be distinguished by the development of two whitish hairs, or stigmas, which develop as part of the pistil—the female flower that appears in branch unions or "nodes."

Cannabis is an interesting species, in that it is one of the only annual plants that produces each of the male and female sexual organs on different individuals. This is a condition known as dioecy; dioecious plant groups contain individual plants that are either male (staminate; stamen bearing) or female (pistillate; pistil bearing). Dioecy is a hallmark of a cross-pollinating species; under normal conditions, cross-pollinated plants (outcrossers) are only able to fertilize other individuals, which has implications we will discuss later.

Although dioecy is most common in cannabis, monoecious varieties do exist. Monoecious varieties produce both staminate and pistillate flowers on the same individual.

These monoecious varieties are mainly used for hemp seed production, as they generate the highest yield of seed per acre. Monoecy is not a desirable trait for drug cultivation, where seedless cannabis, or sinsemilla, is sought.

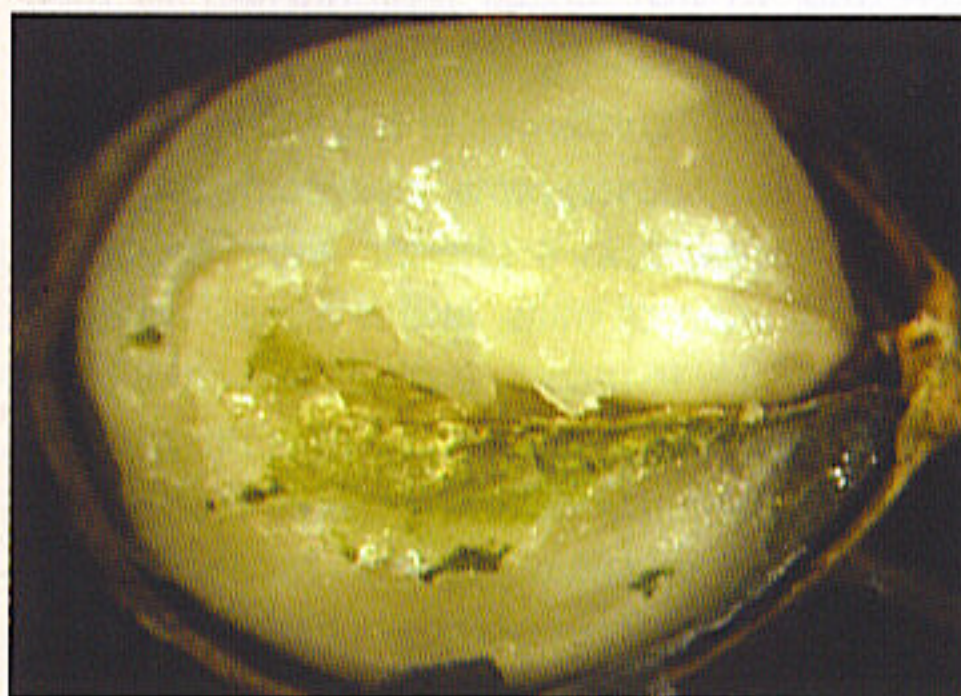
Plants exhibiting both staminate and pistillate flowers are most often referred to as "hermaphrodites" by drug cannabis cultivators but are more correctly referred to as intersex plants. Intersex plants are a problem for growers who wish to produce seedless cannabis for consumption; just as seedless grapes or oranges are more desirable to consume, the same is true for cannabis. Having to remove the seeds from cannabis flowers prior to consumption is an inconvenience, and burning seeds taste bad and can ruin the smoking or vaporizing experience. We will discuss intersex plants in more detail later in the chapter.

The creation of a seed

Cannabis is an anemophilous species; this is a fancy way of saying that it is wind-pollinated. Under natural, or wild, conditions, male plants undergo dehiscence (shedding of pollen) and disperse vast quantities of pollen into the wind. The pollen travels on air currents and, by chance, lands on the stigma or style of a nearby, or not so nearby, pistillate individual. This is the pollination event. Because pollen from many species floats in the air, and there is a significant chance that



Scanning electron microscope photo of the inside of a seed.

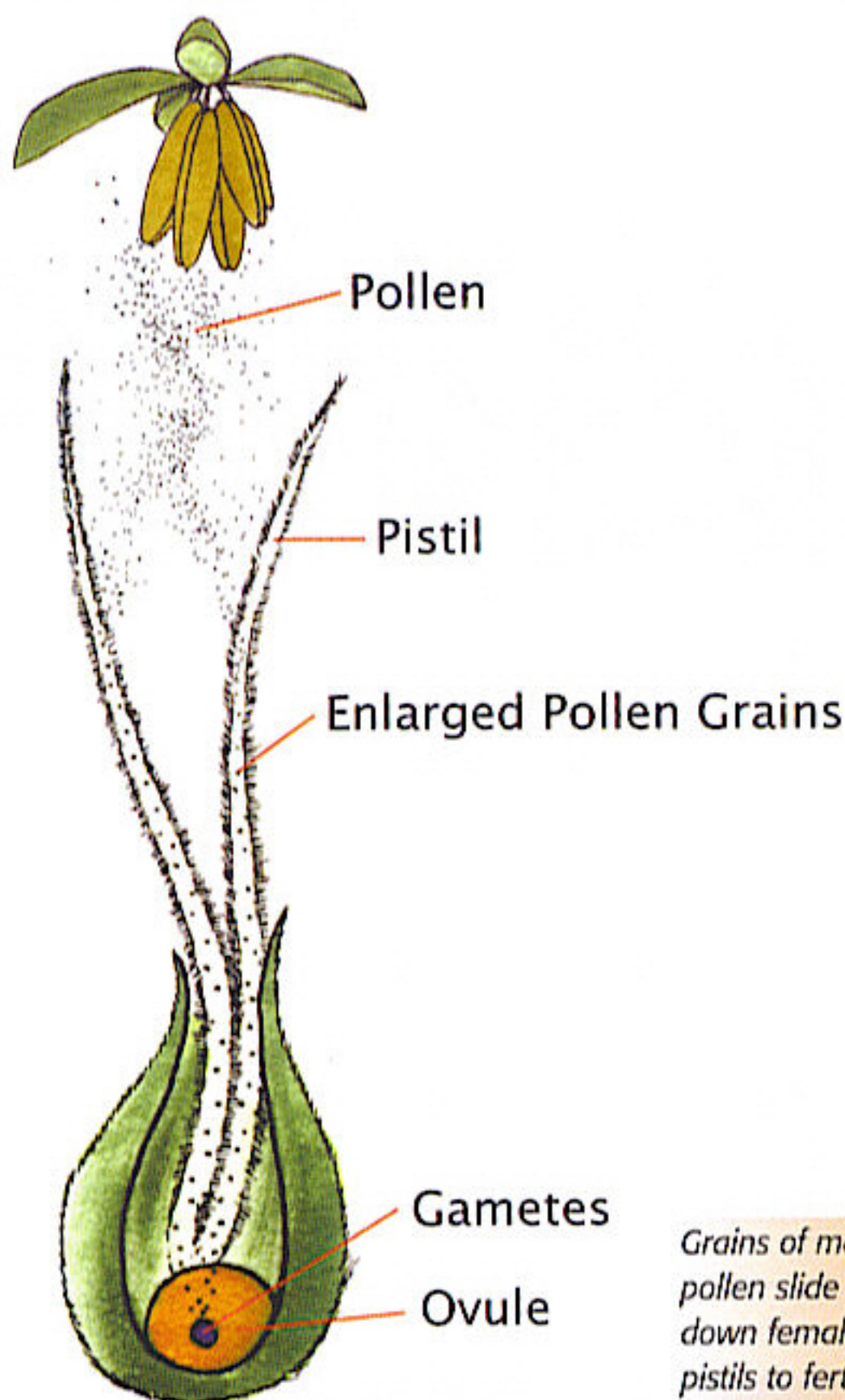


The inside of a seed with half the outer shell removed.

pollen from other species will land on a fertile stigma of a waiting female plant, cannabis has evolved recognition systems that insure only species-specific pollen is able to germinate on the style and thus fertilize the female's ovules. There is physical and biochemical recognition between the pollen grain and the stigmatic surface; together, these insure species identity.

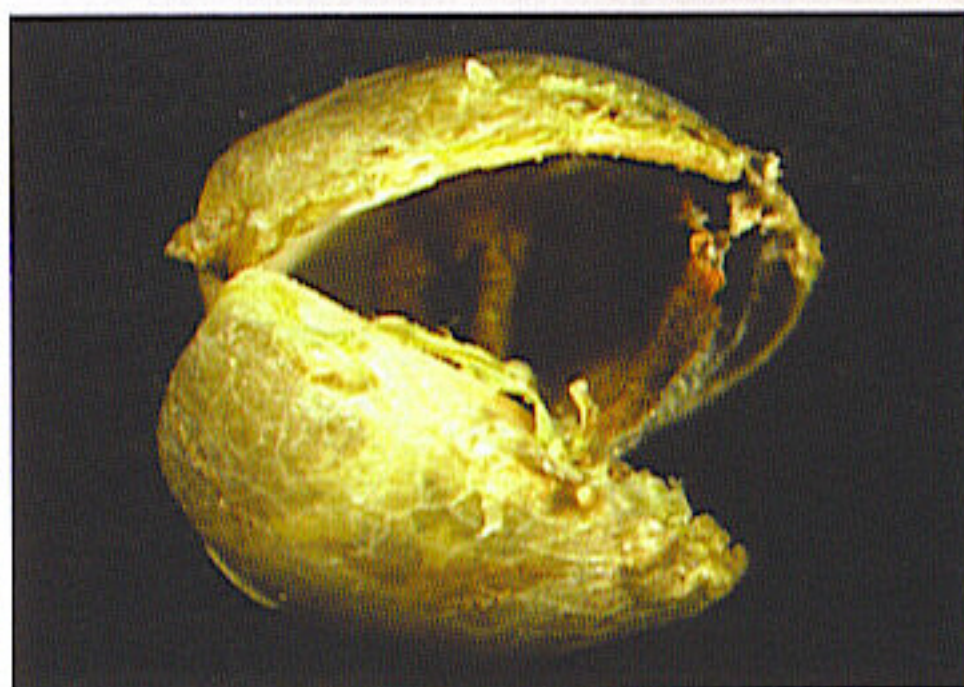
If the biochemical signal is correct and the stigma recognizes the pollen grain as cannabis, the pollen grain is hydrated by a flow of water from the pistil, and it germinates. Just as a seed germinates and sends a taproot into the soil, the pollen grain germinates and sends a pollen tube into the stigma and burrows toward the ovule. Once the tube reaches the ovary, the genetic material carried within pollen is delivered to the ovule, where it is united with the genetic material from the pistillate plant. This fertilization event occurs and creates what is to become an embryo. This embryo grows within a seed coat, and when

Staminate Flowers



Pistillate Calyx

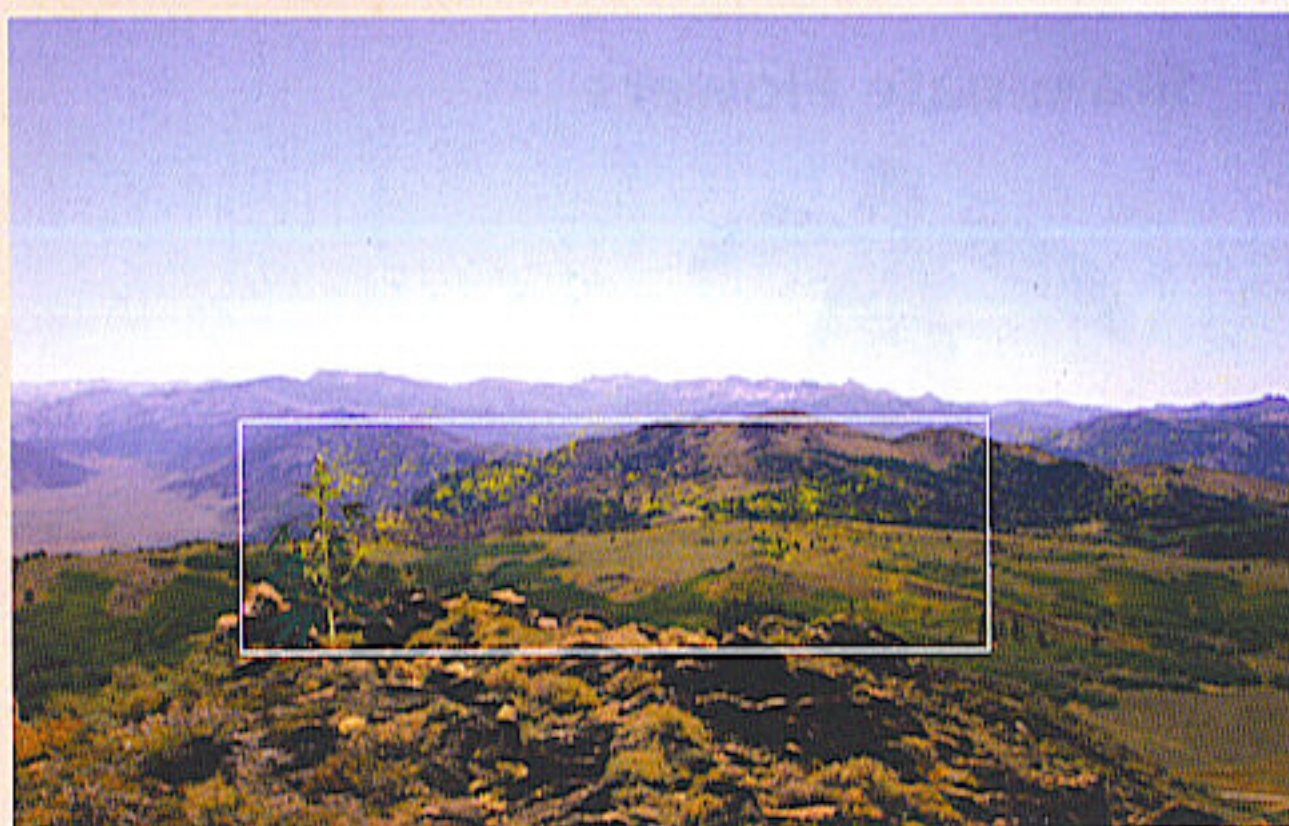
Grains of male pollen slide down female pistils to fertilize the ovule located within the seed bract.



Protective outer shell of a seed.



This germinated seed is the result of much selective breeding.

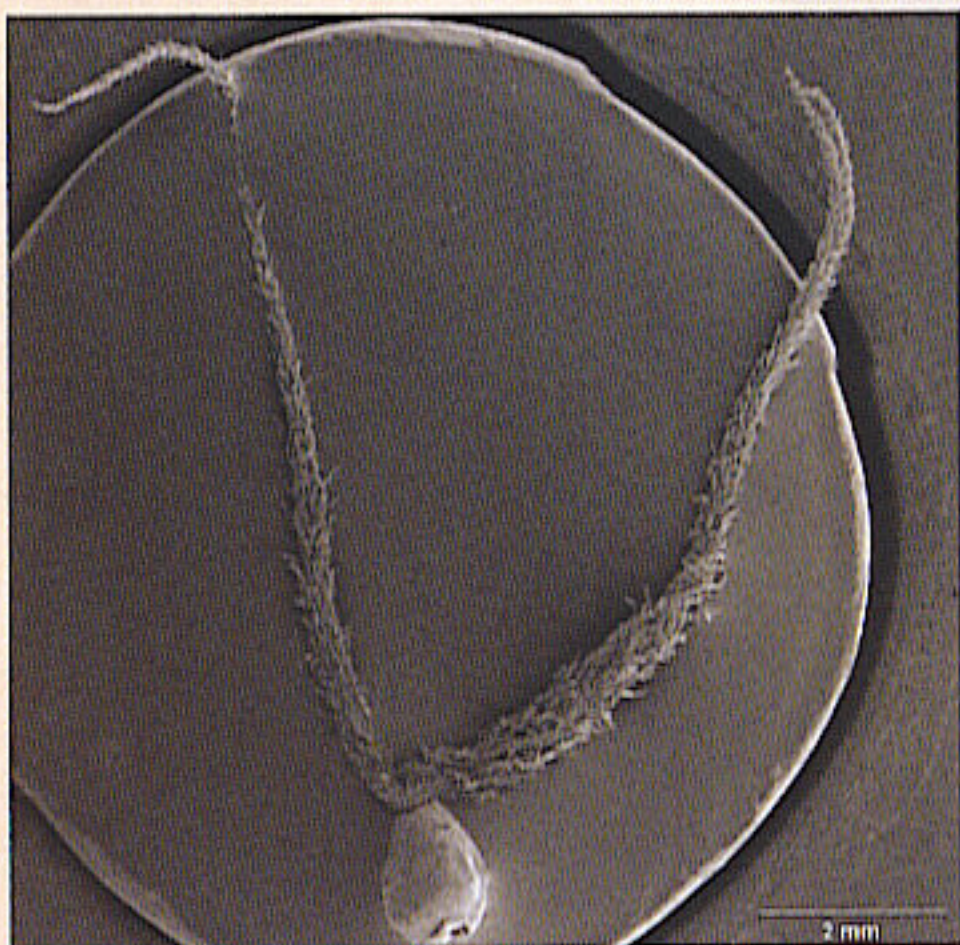


Yellowish clouds of pollen travel many miles to pollinate receptive females.

fully mature in four to five weeks, can be planted and will blossom into a new generation of life.

How to Handle and Use Pollen

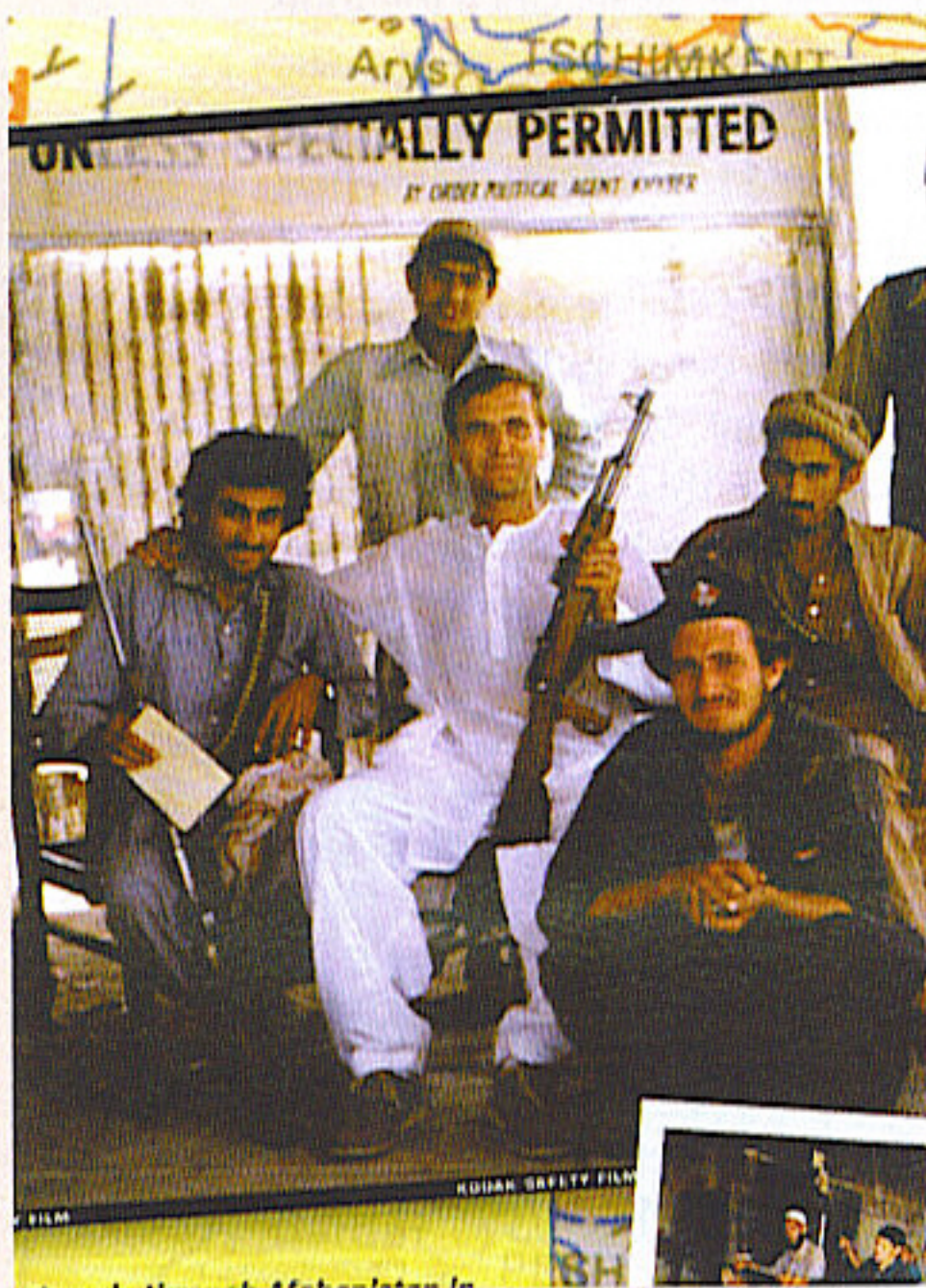
1. Collect carefully
2. Move male as far away from females as possible.
3. Limit pollen travel with filters and water.



Close-up of a pistil shows the complex structure.

General overview and considerations when making seeds

Step One: Choose breeding parents. Selecting female plants for breeding is a much easier task than selecting males, because female plants readily demonstrate all the traits that are essentially important to a grower, or smoker (sometimes these are conflicting interests!). The breeder may want to place an emphasis on selecting for potency, flavor, yield, smell, resistance to pests, color, growth stature, etc. Cannabis for consumption is a group of pistillate flowers; a bud (a bud is a collection of pistillate flowers; a cola is a group of buds). All a grower/breeder/smoker has to do is watch these flowers develop over the life cycle, har-



Ben Dronkers, owner of Sensi Seeds, seated in the center in white, collecting seeds in Afghanistan.

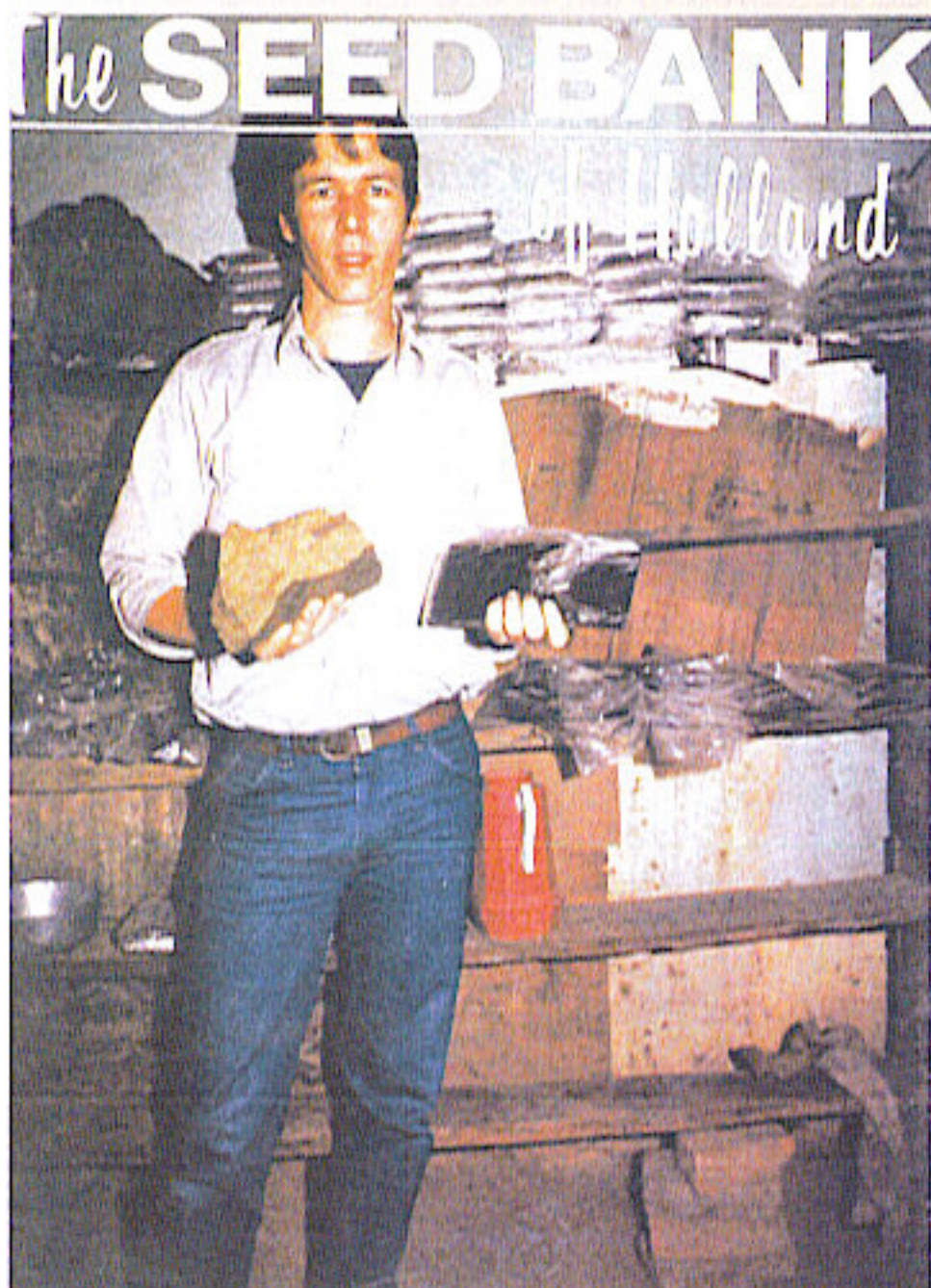
vest, smoke a bud sample from each plant, and determine the positive and negative characters of each plant, for its growth as well as its smoking characteristics. Post-harvest evaluation allows additional inspection of aromas and flavors, since these can change as the flower dries and cures.

Choosing male plants with desirable characteristics is not so easy. Males obviously don't produce female flowers; thus, judging resin content, floral stature, smells, etc. is more of an inferential task—males just don't demonstrate these characters. Some breeders feel a good method for choosing a potential male is to rub the stem with your finger. The idea is if it exudes a pungent, resinous odor, it may be a good plant. This is really only a crude measure of the odor of the candidate. Although it can be a useful technique, it certainly should not be the major selection criteria.

The best method for determining a potential male's contribution as a breeding parent is the

progeny test. Progeny testing is achieved by taking pollen from a potential breeding male and using it to make seeds with the chosen female(s). The resulting seed population is grown out and examined to determine the effect of the male on the progeny. Progeny tests are without doubt the most reliable method for determining the genetic value of the chosen male as a contributor to the next generation—a concept known as combining ability. One drawback of the progeny test is that it takes time to grow and evaluate the progeny, and the potential male plants must be kept alive if they are to be used again. Sometimes breeders choose to not keep these males alive, only keeping the progeny lots that correspond to the better male plants and destroying the rest. Only the best-performing males are allowed to make a genetic contribution to the next generation.

Step Two: Collecting pollen. One branch of male flowers will supply all the pollen necessary for small-scale breeders to produce ample seed



Neville, founder of the Seed Bank, traveled the world to find the best cannabis seeds.



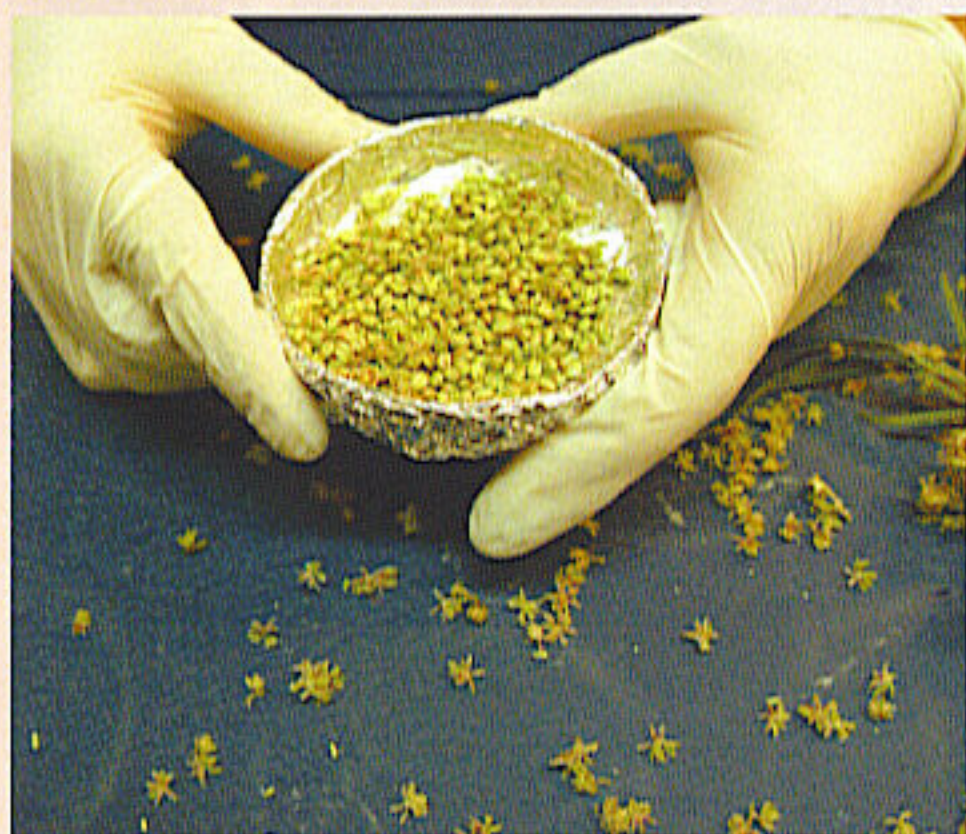
One large healthy male top is all you will need when collecting pollen.



Cut a branch of male flowers and place it in a plastic bag to collect pollen.



Male pollen literally covers this large male leaf.

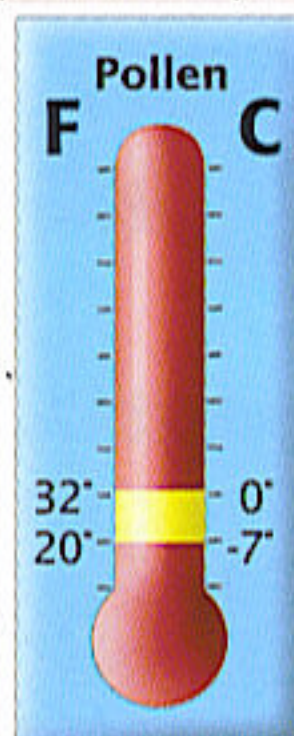


Collect male flowers and separate the pollen with a fine sieve.

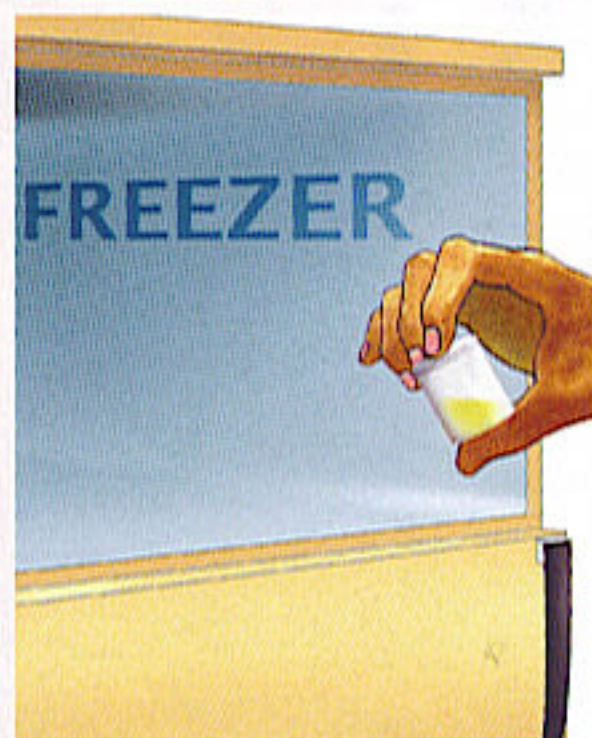
for their own use. Strip away other branches to guard against accidental random pollination, and to avoid premature pollination, isolate the male as soon as anthers show. Be considerate of the fact that airborne pollen can travel miles. If you brush up against a plant in dehiscence, pollen will become airborne and travel throughout the area.

Just prior to the anther's opening, place a clean paper or plastic bag over the branch. Secure the bag at the bottom with a piece of string or a wire tie to prevent pollen from escaping. Keep the bag over the branch for several days to collect pollen. When enough pollen seems to have been collected, tap the branch and shake remaining pollen off into the bag. Carefully remove spent branch and bag so the pollen does not escape.

Step Three: Store and protect pollen (optional). Pollen does not have a long shelf life under natural conditions; it is easily destroyed by high temperatures and moisture. Pollen can, however, be stored in the freezer for several months, if needed. This is accomplished by carefully removing the pollen from the collection bag and subsequently passing it through a screen. This removes any leaf matter from the anthers that may have fallen into the bag and contaminated the pollen, causing it to spoil. Wax paper is placed under the screen, and used to catch the pollen. The pollen can then be collected with a



Store viable pollen at temperatures below freezing.



Store pollen in an airtight vial in the freezer.

sterile scraper, placed in a small coin envelope or sterile test tube, and placed in the freezer. Cleanliness counts! Pollen should not be repeatedly frozen and thawed, which will decrease its viability.

Step Four: Pollination. Pollination occurs when pollen comes into contact with the pistil. Depending on variety, fresh pistils are ready to pollinate from two to twelve weeks after flowering is induced. The more pistils on the bud at the time of pollination, the more seed will be produced. Fertile pistils appear turgid and most often are white or off-white in color. Pistils that are withered, rust- or brown-colored are past the point where successful pollination can occur.

To pollinate, cover the female branch with the pollen filled bag, and briefly shake the bag to ensure the pollen comes into contact with as many pistils as possible. Leave the bag for two days and nights to ensure thorough pollination. Be careful not to scatter pollen when removing the bag, as viable pollen can still become airborne and pollinate any nearby plants. If other plants are in the garden and are not intended

for pollination, the grower may move target plants from the main grow area into a separate, smaller space for pollination. After a couple days in the pollen chamber with the males, the female plants are thoroughly sprayed with water to destroy any remaining pollen, before they are moved back into the main grow area where these seeds will mature over the coming weeks. This practice minimizes the possibility of pollen fertilizing the rest of the crop, keeping it seedless as the cultivator requires. To reduce or eliminate pollen contamination of future seed crops, make sure to clean the pollination chamber between each pollen release.

An alternate approach is to use a small paint brush to "paint" pollen onto the pistils. Dip the



Collect male pollen and put a little on a small artist's paint brush.



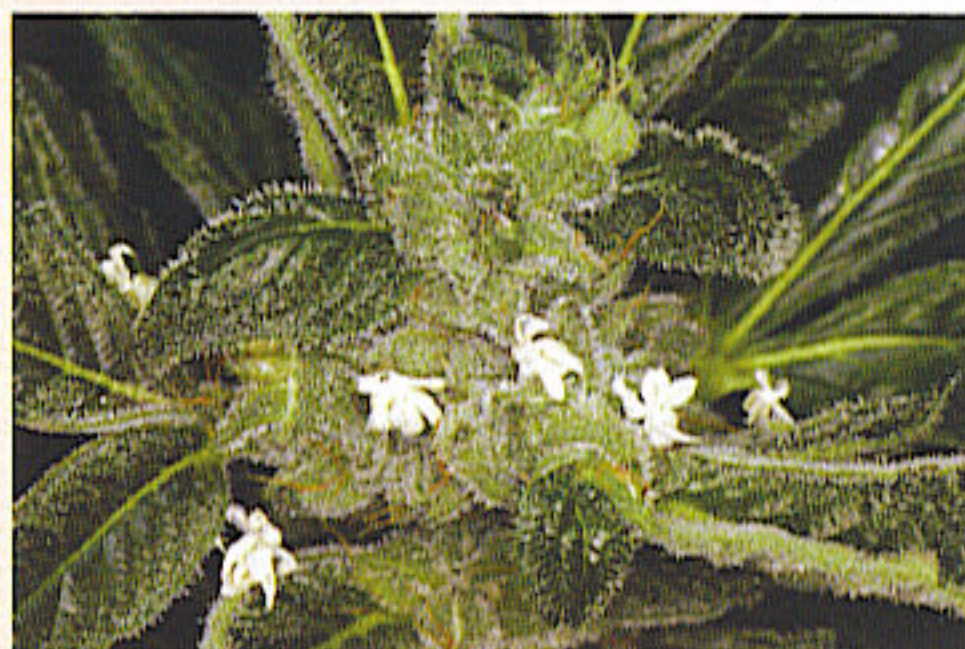
Store male branch in a glass of water.



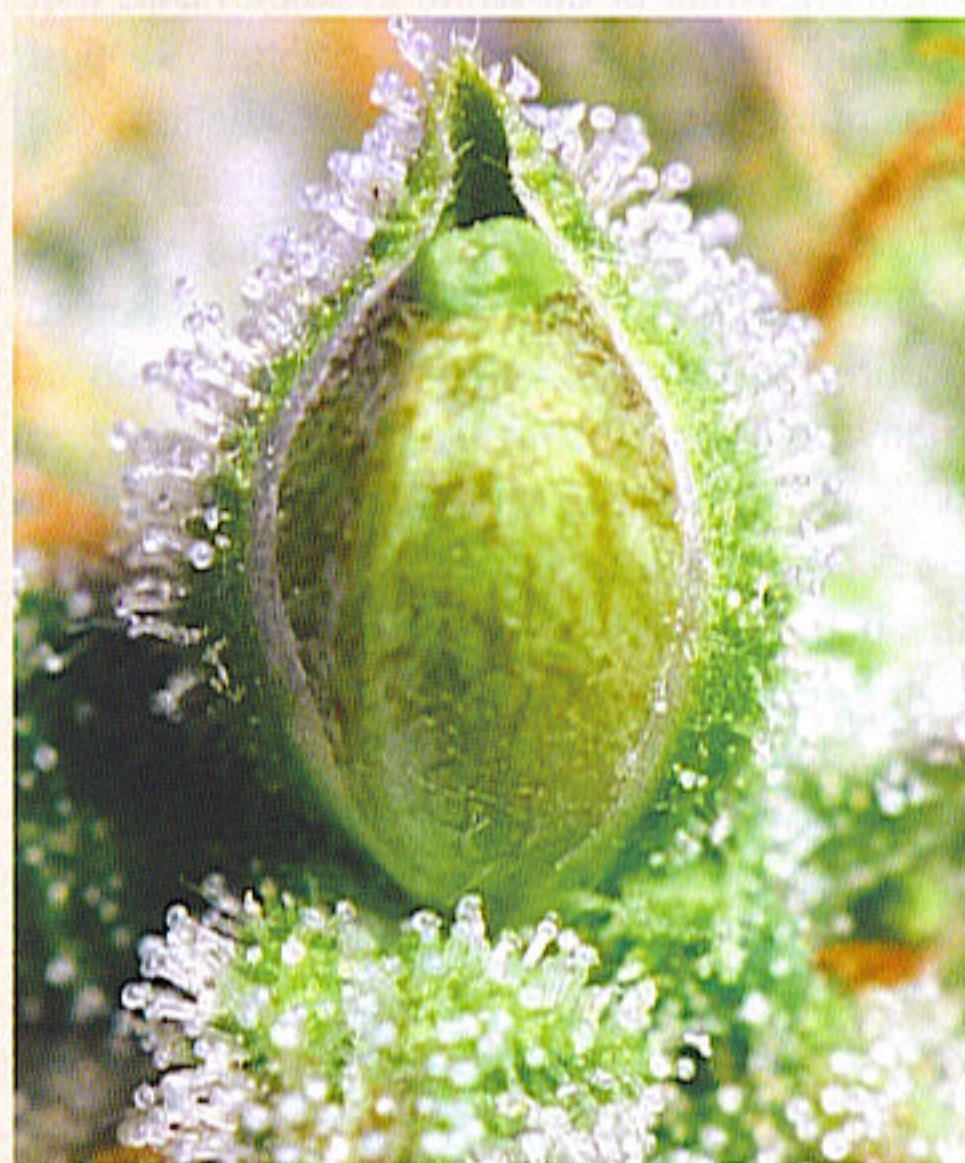
Brush a little pollen on female pistils to pollinate.



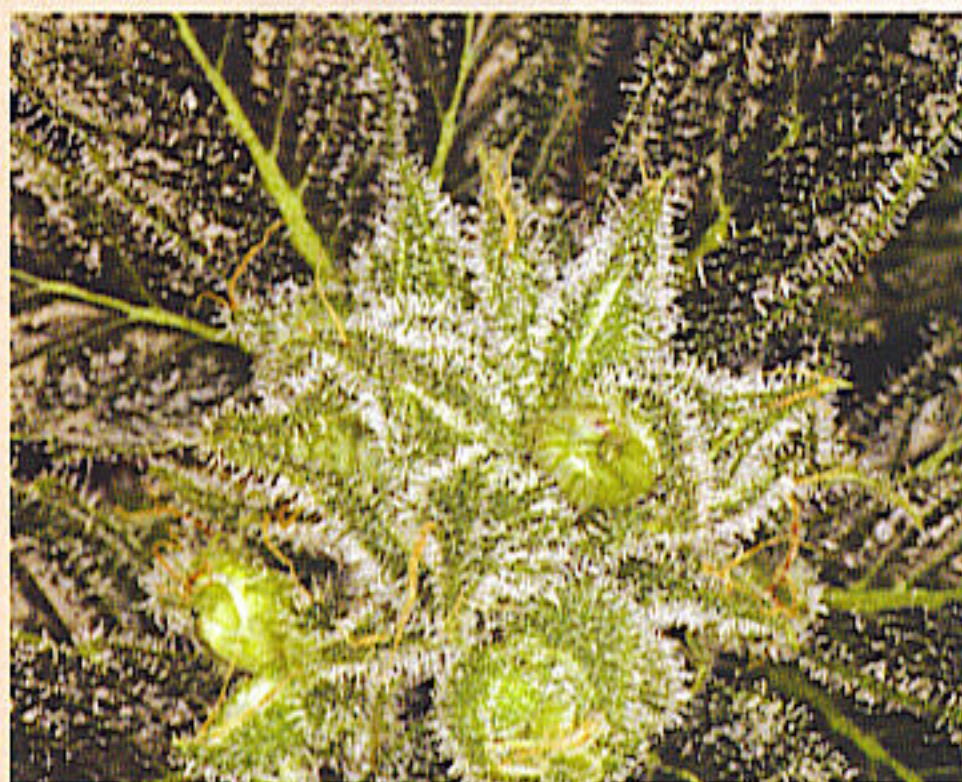
Cover pollinated female branch with a plastic bag to keep pollen from contaminating other females.



Male flowers have fallen and stuck to this fertilized seeded female.



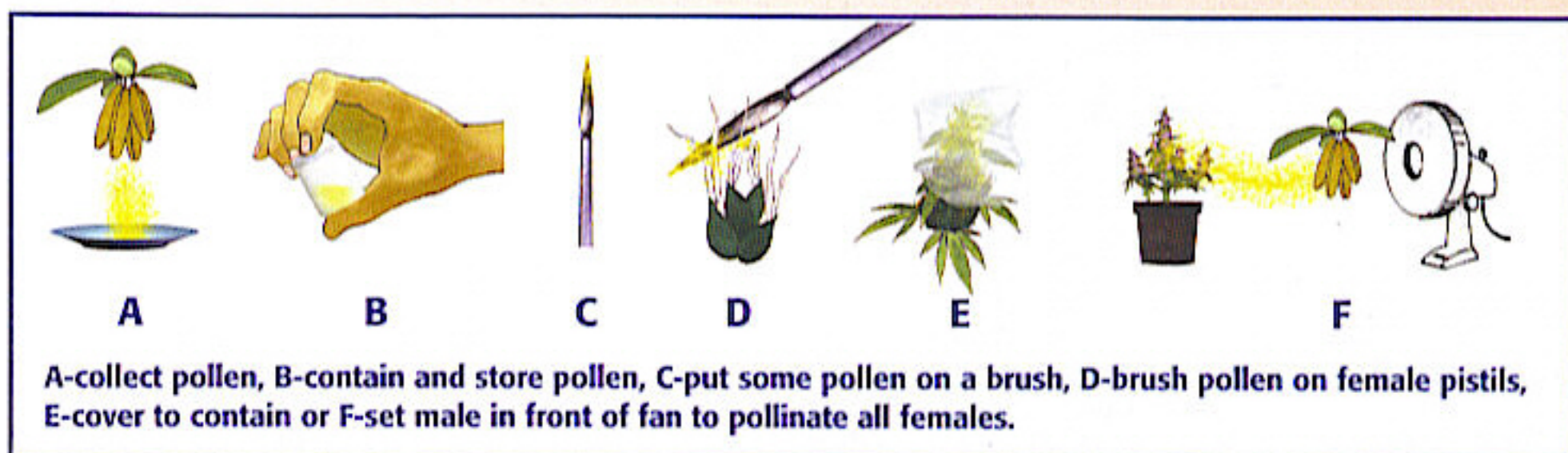
This green seed will be mature in a few weeks. 'Rene' courtesy Chimera Seeds.



Seeded female.



A bathroom is a good place to isolate and breed plants. The male on the right is pollinating the females in the bath tub.



brush in the pollen container and gently brush the pollen onto the pistils. Again, the breeder must have a steady hand to ensure pollen doesn't become airborne during the process. This technique is perfect if the cultivator only needs to make a few seeds.

After fertilization, most seeds will be fully ripe in about six weeks, although some may be viable earlier. As the seeds mature, they can split open the calyxes allowing the breeder to see the development of the seed within. Seeds are ripe when they are mostly dark brown or grey, well-mottled (tiger striped), and sitting loosely in the calyx. Green, yellow, or white seeds are almost always immature and not viable. (Sprinkle them on your salad or cereal.) To test the ripeness of the seed crop, you can sample-harvest a few seeds and try to press them between your thumb and index finger to test the firmness. If most of the seeds do not crush with a reasonable amount of pressure, it's time to harvest. If seeds are left on the plant too long, some may fall out of the buds and germinate on the growth medium below. This is more common with *sativa*-dominant varieties. *Indica* varieties typically have more dense flowers, which hold the seeds more tightly. Breeders must remove seeds from *indicas* by crushing and sorting the seeds from the plant matter.

Seeds are ready to plant immediately, but the initial germination rates may be low. Germination rates can be increased by drying seeds out post harvest, leaving them in a cool, dark, well-ventilated area for a few weeks, and then placing them in the refrigerator for one or two months before sprouting.



The seed can be seen inside of the seed bract in the circle. The bud on the left contains a mass of seed bracts filled with seeds.

Please keep in mind this is only a guideline intended for small-scale seed production. Any method where pollen comes into contact with a pistil will result in seeds. Often breeders and seedmakers will place multiple males, or multiple copies of the same male (clones from a father donor plant) in the seed production grow room with their chosen females when creating seeds. Placing these males in a well-ventilated room and allowing full release of pollen ensures the crop will be completely pollinated, and produces a vast amount of seeds per plant. Scale the process to suit the number of seeds you require.

Seed Crop Care

Typically, cannabis growers use a high-phosphorus, low-nitrogen diet during the flowering cycle. My personal philosophy is to give seed production plants a complete balanced diet



Young seedlings require a complete balanced diet.



Vegetative and flowering plants require the same fertilizer for good seed development.

throughout the seed gestation period, so all nutrients required for proper development of the seeds are available. Because most cannabis-specific flowering fertilizers are low on nitrogen, growers may wish to combine vegetative and flowering fertilizers to ensure a complete diet for their seed mothers. Flowering nutrient formulas often lack certain nutrients, and the gestation period is not the time to be starving plants of these needs. Provide a complete diet, and let the developing seeds have all they need.

I've found that complete, balanced, organic-based soil mixes produce the most healthy, viable seeds. Organic soils contain various bacterial populations that break down and digest soil amendments to make them usable by plants. 'Sterile' salt-fertilizer based soils do not support these bacterial populations, and while they do support plant growth, they lack the "alive" quality of an organic soil. Many growers agree that organically grown pot has more flavor and taste than pot grown on a synthetic salt diet. It could well be that these organic bacterial populations provide some benefit to plant health, and thus produce more mature, healthy, viable seeds.

In order to have a discussion on breeding, there are some terms we must learn in order to fully understand the concepts. There are more terms defined in the Glossary.

Genetic material is inherited as described above, in the seed making section, from both the pollen donor and mother plant. The genetic material, or deoxyribonucleic acid (DNA) is coiled into long, X-shaped strands called chromosomes and stored in the nucleus of every cell. In cannabis, each individual inherits 10 different chromosomes from the staminate pollen parent, and 10 different chromosomes from the seed mother or pistillate parent. The resulting individual has 20 chromosomes total; 2 copies of each of the 10 chromosomes, or 2 full genomes. This means there are 2 copies of every gene in the plant, one from the mother and one from the father. Each and every cell in the plant has a copy of this unique DNA compli-

ment. The genetic code is written along the length of the chromosome strands, and each gene has a specific location along its length.

Phenotype - We consider phenotype as the observable, qualifiable, or quantifiable representation of a given trait. Anything you can measure, categorize, or otherwise observe in an individual can be considered a phenotype. Every plant has many different phenotypes. For example, plant height might be broken down into three categories or phenotypes: short, medium, and tall stature. There is a short phenotype, a medium phenotype, and a tall phenotype.

Cannabis flowers demonstrate different color phenotypes as well. Most often we see green calyxes, but there are also plants that have purple calyxes. Sometimes there are even green calyxes with purple markings. These are all different calyx-color phenotypes. There are also calyx-size and calyx-shape phenotypes, or leaf size and shape phenotypes. Every trait has different phenotypes that can be selected for or against.

All phenotypes are the observable result of genes acting within the cells of the plant. Sometimes a single gene controls one trait (monogenic traits), and sometimes sets of genes operate together and contribute to make what we see as a phenotype (polygenic traits).

Genotype - The genotype of a plant is a way of describing the actual genetic condition that results in the phenotype. As the genetic constitution or makeup of an individual, genotypes are not always expressed. Some are latent and only express themselves given the proper environmental stimulus. For example, some plants have green leaves, but the leaves will turn purple under cold conditions. Other green-leaved plants will not turn purple even under cold conditions.

This happens because these plants have a different version of the gene(s) that control whether purple pigments are to be produced in the leaves. These different gene versions are called *alleles*.

These plants initially both had the green-leaved phenotype, but one plant developed an altered phenotype (purple leaf) in response to an environmental condition. This is due to an interaction of the genetics of the particular plant with respect to this trait (genotype) and the environment.

A simplistic way to think of the concept is:

$$\text{Phenotype} = \text{Genotype} + \text{Environment}$$

Remember, this isn't 100% true. More accurately, the phenotype(s) seen in a given individual are the result of an interaction of the plant's genotype with the environment.

Let's look at some possible corresponding genotypes in our short, medium, tall phenotype example. Remember, the genotype is our way of describing the genetic condition responsible for the phenotype, therefore we can assign it whatever values we want, it's really just a symbol.

Phenotypes	Genotypes
Short	ss
Medium	Ss
Tall	SS

There are always 2 alleles, or versions of every gene, including the gene responsible for stature. When we have 2 "s" (lower case s) or "small stature" alleles, we see the short phenotype in the plant. Conversely, when the plant has 2 "S" (capital S) or tall alleles, the phenotypic outcome is a plant of tall stature. If the plant happens to inherit a copy of the tall and short allele, the resulting phenotype is a plant of medium stature.

Often, breeders base the symbol for the genotype on the first letter of the recessive expression of a trait. What this means will become clear over the next paragraph or so.

Homozygous / Heterozygous - These are terms used to describing the genotypic condition of a plant, with regard to the similarity of the alleles for a given trait. If a plant is *homozygous* for a given trait, it has two copies of the same allele (homo = same). If a plant is *het-*

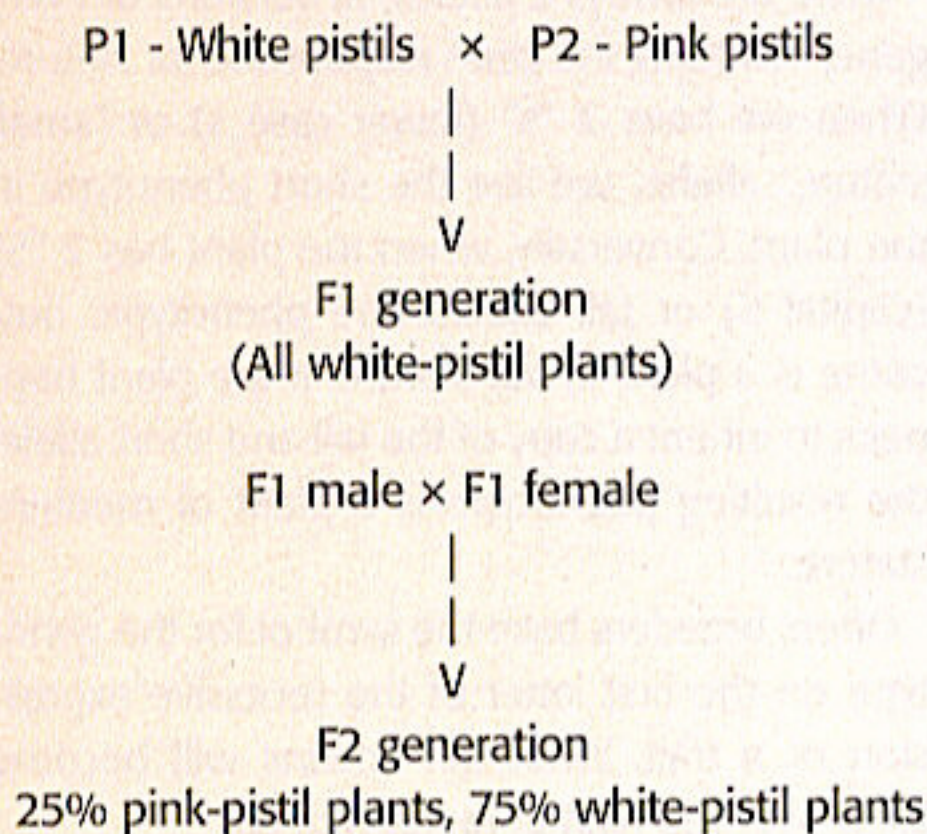
erogous, it has two *different* alleles for a given trait (hetero = different).

Dominance

Consider two true-breeding varieties; a white pistil variety and a variety showing only pink pistils. Both conditions are true-breeding and therefore homozygous; in each case sexual reproduction of each group separately leads to only pink pistil or white pistil plants respectively. An F1 hybrid, or first generation cross of these two varieties, results in only white pistil plants; no pink pistils are seen regardless of how many F1 seeds are grown.

Upon sib mating of these F1 plants (crossing brothers to sisters, or mating F1 siblings), the resulting F2 generation produces 75% white pistil plants and 25% pink pistil plants. Notice the "disappearance" of the pink pistil plants in the F1 generation, and their subsequent "reappearance" in the F2 generation. In this case, white pistils are said to be *dominant* over pink pistils, and pink pistils are said to be *recessive* to white pistils.

Again, let's consider the phenotypes seen, and provide symbols and deduce the genotypes:



Remember our rule about naming the genotype symbol based on the first letter of the recessive condition, in this case pink.

Phenotypes: Pink (recessive) and White (dominant)

Phenotype	Genotype
P1 - (pink pistils)	pp
P2 - (white pistils)	PP
F1 - (White pistils)	Pp
F2 - (White- and pink-pistil plants)	
25% Pink	pp
75% White	P

This 75% can be broken down into 2 genotypic classes, PP and Pp.

When we cross Pp × Pp plants, we get three possible combinations of genotypes. 25% PP, 50% Pp, 25% pp.

	P	p
P	PP	Pp
p	pP	pp

Therefore we know the 75% white pistil plants are actually 50% Pp + 25% PP, for a total of 75%.

Recessive: an intra-allelic interaction such that an allele of one parent is masked by the presence of an allele from the other parent plant, in the expression of a given trait in the progeny. The recessive trait is not shown in the first generation of progeny (F1) but will reappear if siblings are mated, and the F2 progeny will result in 25% plants showing the recessive condition.

Dominant: an intra-allelic interaction such that the presence of an allele of one parent masks the presence of an allele from another parent plant, in the expression of a given trait in the progeny. Only the dominant trait is shown in the first generation of offspring. Of the F2 generation, 75% will also show the dominant condition.

Primary Components of a Breeding Program

1 - Develop a vision or a breeding goal.

Every breeding program should begin by developing a breeding goal. Why are you trying to make seed? What are you trying to accomplish by mating these sets of parents? You might be trying to make a seed population that represents the traits of an ideal, or mostly ideal plant you have previously selected. In the case of the latter, you might be trying to add new traits to your mostly ideal plant and incorporate these new traits into a new seedline. Some may just want some seeds to plant for next year's crop. Think of your breeding goal as your final destination; the breeding process is the roadmap or route to get to that goal.

2 - Find or Create Variability.

Finding variable seedlots these days is certainly not a difficult task, because very few breeders take the time to stabilize or fix certain traits within a given breeding population prior to release. Your starting seed stock likely represents a range of variation for most traits, depending on the source of your initial starting material. The sad reality is that most of the seed industry today focuses more on creating seed for sale than on developing improved or even uniform plant stock. As a breeder looking for germ plasm to work with, this leaves unstable populations with ample variation for future selection. If searching for variation, this could be considered a good thing. However, since true-breeding stable plants are what breeders look for when choosing stock for their own breeding, this is a hindrance as well. It is much easier to breed with true breeding plants because one can see patterns emerging in a predictable manner in subsequent generations, and thus expect reliable, consistent results when hybridizing known true-breeding parents. This can only be achieved if the breeder is using true-breeding starting parent stock. Due to the lack of commercially available true-breeding stock to work with, serious breeders must stabi-

lize their initial breeding stock before beginning the hybridizing or out-crossing phases of their breeding programs.

3 - Grow and evaluate.

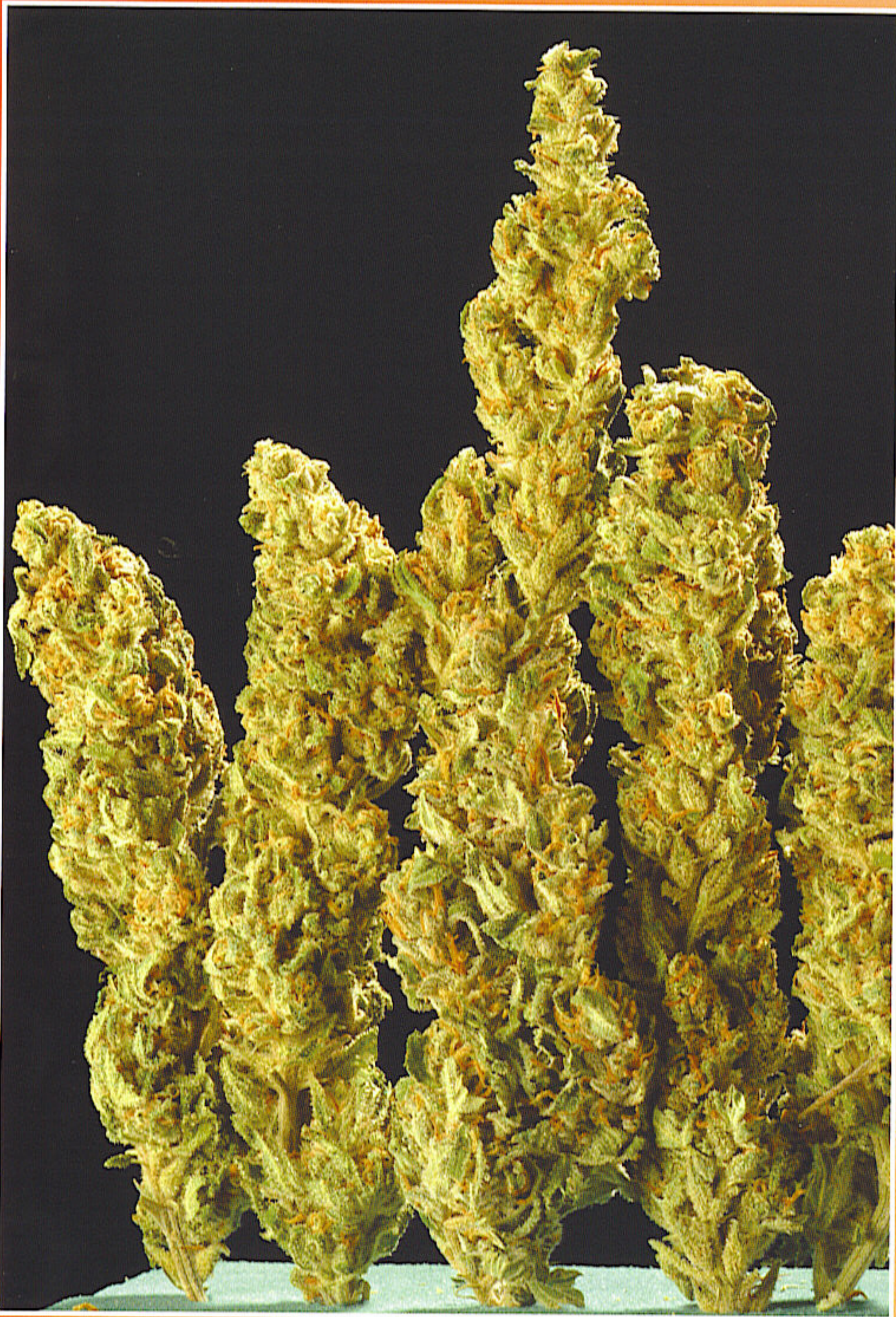
Do just as it says. The more plants you grow, the more variations you will see. I am repeatedly surprised and even amazed to see new expression of traits when growing this fabulous species. Cannabis is an extremely variable and polymorphic species, many traits have numerous possible expressions. Growing varied seed stocks of different heritage (and many of each population) ensures the breeder a wide array of phenotypes and combinations of traits for future selection.

Choosing from as many plants as possible is always preferable; having a wide and diverse starting stock assures the highest chances of finding what you might be looking for. When selecting from just a few seeds, it's not possible to assure all plants will be vigorous or show the traits of interest even if they are seeds of known quality. Breeders must weed through large populations of potential plants, and "rogue out" the undesirable individuals. In any breeding program, off-types which do not suit the goal should be removed from the breeding populations.

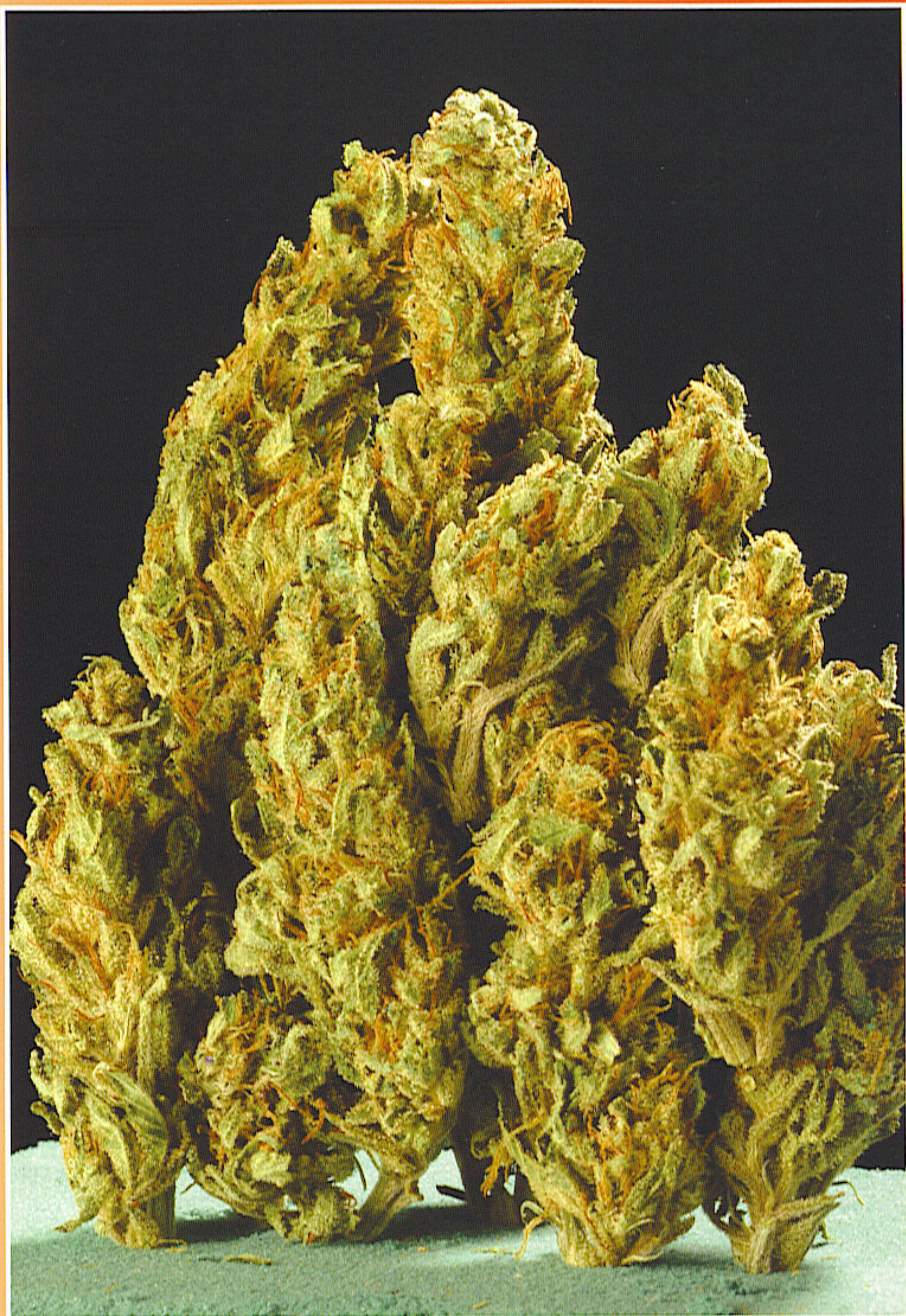
Some recessive traits, especially those controlled by multiple genes (polygenic traits), have the potential for phenotypes that are only apparent in 1 in 100 or even 1 in 1000 plants. Unless growing many individuals, the breeder has a very low likelihood of discovering these phenotypes. All other things being equal, the breeder who grows the most plants has the greatest possibility of finding the best breeding candidates. Testing the final product is a crucial part of the evaluation process, so get out that bong or those rolling papers and put all your hard work to the test!

4 - Screen, Select, and Apply Selection Pressures.

To paraphrase one of the great breeders of the 20th century, select only plants that closely



Of the many 'Skunk' and 'Skunk #1' plants available, 'Ultra Skunk' is one of the most homogenous and true breeding.





Rogue out weak females.

match your goal, and reject all others. This is an important rule to follow if your future generations are to gradually approach your goal.

Breeders select plants for future breeding on the basis of their desirable characteristics. There is no "right" or "correct" ranking of priority for selecting one trait over another; this is purely based on what traits are most important to the breeder. For indoor cultivation, these include short, squat, bushy growth; large, densely formed buds; discernible taste or particular flavors and aromas; high THC content and quality of high (long-lasting, soaring, sedative); and resistance to specific insects or diseases. It's a good general rule to look for plants with overall vigor and good health.

Sometimes, we find a plant that is almost ideal in every respect, but has some negative trait that is undesirable. For example, the breeder may select a highly potent plant that produces exceptionally aromatic or flavorful flowers but is tall and lanky and difficult to grow indoors under artificial light. Even with this negative trait, the breeder decides the plant is a worthwhile breeding candidate. The breeder must realize and note that when selecting plants that may have some genetic weakness, the unwanted negative traits must be removed from the population at a later point. The breeder must balance positive and negative aspects of each plant as a possible genetic contributor to future generations.

When planting a large number of seeds, you will generally find that some plants differ greatly in regard to certain traits while being otherwise nearly identical. For example, some plants are more-or-less susceptible to fungal infection such as *botrytis* (grey mold) or powdery mildew. Once suitable plants are selected, they can be exposed to a particular pathogen or environment as a selection pressure; growing potential breeding parents in an environment may expose genetic strengths or weaknesses associated with a particular environment. For mold resistant varieties, select plants for future mating that resist mold in a mold prone environment. For potent varieties, select only the most potent plants, after harvest. If you require your plants finish at less than 6 feet of height, remove or only keep seeds from plants that mature at less than 6 feet. If you require an outdoor acclimated variety, perform your selection outdoors under those particular conditions, and put an emphasis for selection on plants that mature early enough to finish in your particular environment. Selecting the earliest of the most potent plants is a better way to preserve potency, than selecting the most potent of the early plants. It really depends on what traits the breeder ranks in importance to the program, a decision based on the breeding goal.

Usually, varieties that perform well under artificial lights will also perform well outside or in a glass house under natural sunlight after two or three years of acclimation. The converse doesn't hold true nearly as often. Varieties that perform well outside, especially pure *sativa* varieties, often prove disappointing when grown under artificial light.

Post-harvest selection requires either partial seeding of each plant (only seeds from the most potent plants are sown for successive generations) or keeping clone copies of each and every plant, for future seed production use once post harvest evaluations are done.

5 - Commercialize.

This is an optional part of a breeding program. Some people breed to create a variety that suits their specific growing environment and smoking tastes, without ever intending to profit from the sale of their work. They just want reliable seeds for their own planting and future use. Some are of the opposite extreme; they make seeds exclusively to sell. These "breeders" do very little breeding. We refer to them as seed makers.

Because cannabis is a species under attack from various governments and other evil forces around the world, true breeders with goals and intentions other than financial are sorely needed to protect the genetic resources cannabis has left. Years of persecution from governments and greedy seed-making practices without improvement or preservation have led to a genetic bottleneck, a narrowing of the potentially available breeding stock. Now more than ever, ethical breeding should be of utmost concern to cannabis enthusiasts. The species desperately needs breeders who are willing to improve populations in their possession, all the while preserving valuable genetic resources for future generations of breeders.

Sam the Skunkman, a great ally of cannabis, says we all stand on the shoulders of those who have come before us. We can build upon the improvements our ancestors have made to landraces and wild populations, but we can only work with what they have left us. Selections and advancements come at a cost to genetic variability. Breeders often reduce variability by narrowing the gene pool of that particular population as a consequence of fixing traits. The best breeders strive to advance and improve a given variety or population while preserving the variation present for the traits not under selection, which may prove valuable for future breeders and growers.



Growing out a large number of seedlings is the best way to find a good mother plant.



You can find just about any marijuana seed you can imagine on the market today.

Types of seed populations

Inbred Line/Pure Line

Some refer to these as IBLs. An inbred line is a seedlot that has been bred for generations while selecting repeatedly for specific traits, to the point where the population reliably reproduces the traits under selection in each successive generation of breeding. These plants are said to breed true for these characteristics. There

is little or no variation for these traits, which are thus considered pure. Pure lines make the best breeding stock as the progeny of crosses using known pure parental lines have a predictable outcome in subsequent generations. Inbred lines are uniform in growth patterns and traits and are stable genetically—each generation of inbred seed results in plants similar in most ways to the previous generation. Pure lines are homozygous at most alleles.

Hybrids

Hybrids are a product of a cross between genetically unlike parents. Hybrids retain their distinctive characters if reproduced asexually but fail to reproduce these characters completely or reliably when reproduced sexually. Hybrid cultivars are developed by using available inbred lines or creating new ones from segregating populations, and then coupling selection with inbreeding for homozygosity, evaluation of inbreds for combining ability in hybrid combinations, and subsequent multiplication of selected inbred lines for hybrid seed production.

There are various types of hybrid varieties:

F1 hybrids ('Northern Lights' × 'Blueberry', 'Northern Lights' × 'Haze', 'Frostbite')

3-way crosses ('Skunk #1' - a cross of (Mexican × Columbian) × Afghani)

Double cross hybrids (a cross of 2 unrelated F1 hybrids 'Haze' (Afghani × Thai) × (Mexican × Columbian)).

F1 hybrid varieties -

An F1 hybrid population is obtained by crossing two unrelated, true breeding varieties. F1 hybrids are unique in that they are uniform when grown from seed, but, like all hybrids, are genetically unstable. If reproduced sexually by inbreeding within the F1 population, the subsequent generation will be neither uniform nor similar to the F1 generation.

One of the major benefits of F1 seed to the grower is a condition known as hybrid vigor, or heterosis. Hybrid vigor occurs when the progeny resultant from crossing the two parental inbred lines exceed the performance of the parental lines in some character, or most often in sets of characters ($F1 < \text{or} > P1 \text{ or } P2$).

F1 hybrids are often bigger and more robust and grow faster than either of the parent populations used in the creation of the F1 population. For example, a ('Skunk#1' × 'Blueberry') F1 hybrid may grow faster and yield more than either the pure 'Skunk #1' or 'Blueberry' parent populations. Often, heterosis is apparent as a tolerance to adverse environmental conditions.

F1 seed production has benefits to the breeder or seed-maker, as well as the grower. True-breeding seed can be easily reproduced by open-pollination. Most seed companies have no interest in selling easily reproduced seed. This is as true of corn as it is of cannabis. Very few companies that do take the time and effort to breed stable parent stock release it in a pure form. Most make and release hybrids, as certain competitor companies' sole mission is to create knockoff versions of lines released by those who have actually taken the time to develop new true-breeding lines. By releasing only hybrids of their pure lines, seed banks ensure the customer comes back to buy more of the F1 seed each time they wish to do a new seed planting of the variety. They also protect the investment of their long-term breeding effort by removing the possibility that a competitor will reproduce their work and sell it as their own.

Unfortunately, breeders of cannabis drug varieties have no recourse to the law when others reproduce and market their years of work. Due to the illegal nature of the plant, drug cannabis varieties are not protected by the various plant breeder's rights legislation around the world. There is, however, at least one drug type cannabis clone registered for plant protection in Holland. The clone registered as 'Medsins' is owned for use by a pharmaceutical company

licensed to grow cannabis for pharmaceutical production.

Variety - A subdivision of a kind, group, or family that is distinct in some characters. Within the variety, all plants exhibit a set of defined morphological, physiological, or other chemical characteristics that differentiate the variety from all other varieties. *The variety must be uniform.* Variations in essential and distinctive characters are described and characterized by the breeder. The variety will remain unchanged to a reasonable degree of reliability in its essential and distinctive characteristics and its uniformity when reproduced.*

Cultivar (abbreviated cv) - A term derived from "cultivated variety," a population of cultivated plants clearly distinguished by any number of morphological, physiological, cytological, or chemical characteristics. When reproduced sexually or asexually the population retains its distinguishing characters.*

New selections derived from a cultivar or variety such that the selection shows sufficient variation from the parent cultivar to render it worthy of a name, are to be regarded as a distinct cultivar.

* *Note that the Guidelines for Classifying Cultivated Plant Populations (1978) stipulate that variety and cultivar are considered equivalents.*

Strain - Strain is not a scientifically accepted botanical term, although in the cannabis industry many use the term when discussing seedlots for purchase, for lack of a more accurate term. Strain is a term incorrectly applied to selections of cultivars or varieties. In the cannabis seed industry, very few seedlots could be considered true varieties or cultivars, because they are not uniform or do not breed true. All plants within the population do not reproduce the defining characteristics, and, usually the variations in the defining characteristics are not described. Very often, commercially sold seeds are nothing

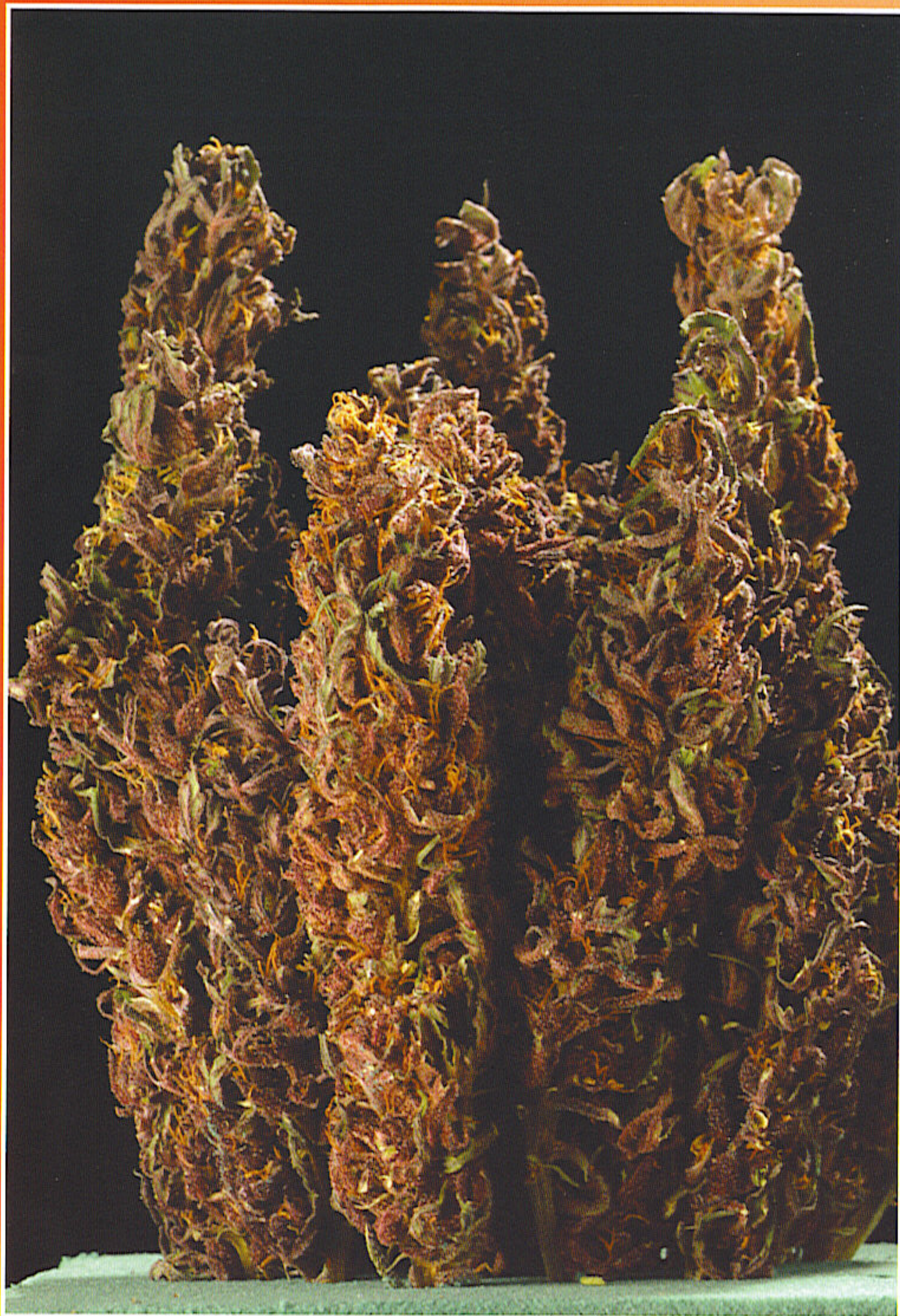
more than hybrids of hybrids with names, and there are no defining characteristics of the "strain." Perhaps "family" or "group" are more appropriate terms.

Open Pollinated Varieties - Non-hybrid populations reproduced by random pollination within the variety. All pistillate individuals have the potential to mate with all staminate individuals as the pollen spreads randomly, ensuring preservation of the genetic diversity within the breeding population. In cannabis, open pollination is carried out by planting the breeding population together in a given plot isolated from other pollen sources and left to the will of the wind. To maintain varietal purity, hemp breeders ensure there is no non-varietal pollen source within four miles upwind, and one mile downwind—which should demonstrate just how far cannabis pollen can travel on the wind.

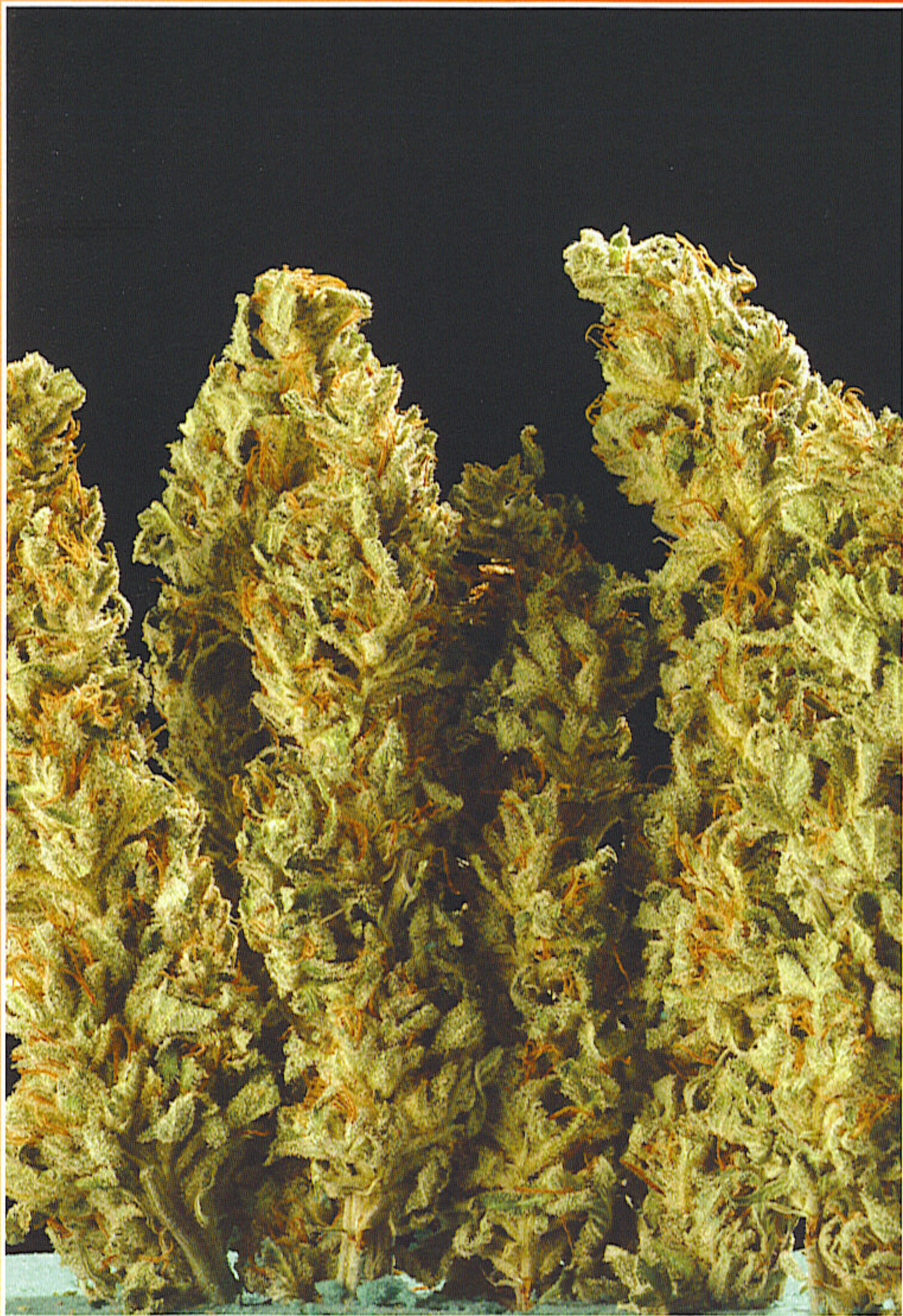
Heirloom varieties/Heirloom seeds are the product of many years of selective planting and seed saving. The original seeds bore a plant or flower that had particular traits the grower liked—typically flavor, color, or psychoactive effect. The grower then saved the seeds from the desirable plant and repeated the process the next season selecting for similar type plants. The term "heirloom seeds" came about because the selection process for some cultivars has been going on for generations, often passed along within a family and/or shared with friends.

Heirloom varieties are non-hybrid (open-pollinated). This simply means that they breed relatively true. Thus, growers can save seeds from their crops, plant them the following year, and expect to see offspring that are very much like the parent generation. Any off-types in each generation should be rogued out of the breeding population to keep it pure, as they are likely the result of pollen contamination from an external source.

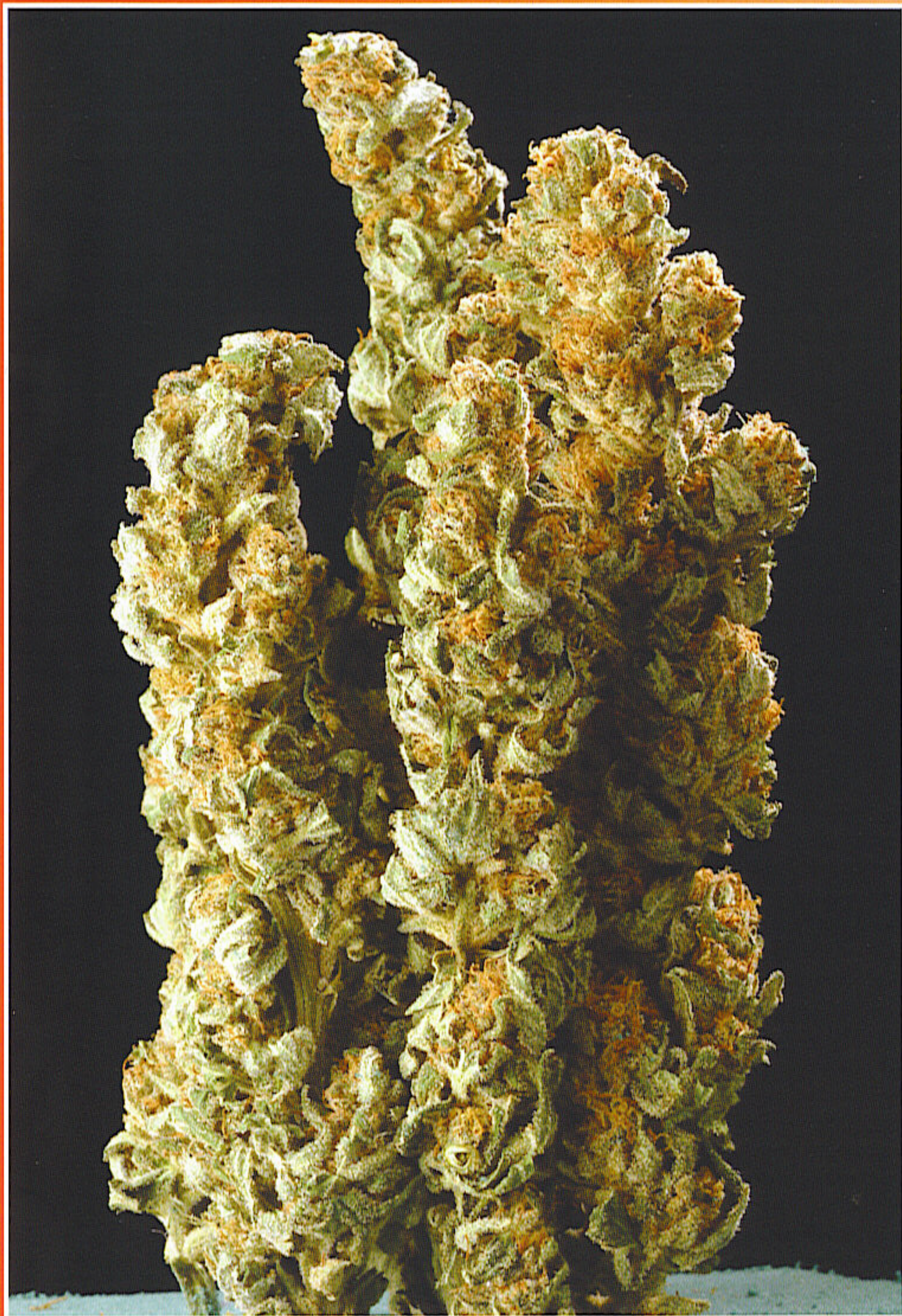
Multi-line - Two or more pure breeding lines, which are very similar, but differ in a small part of the overall phenotype (i.e., maturation, dis-



'Purple Haze' could be classified as a "cultivar" or "variety."



'Mr. Bubble' is an example of a cannabis variety.



'Silver Blue' could be used as an example of a strain.



'Thai' buds are a good example of an heirloom variety.

ease resistance). The varieties are grown and bred separately but are subsequently mixed together and sold in the same seed package. These packs are a benefit to growers if the grower's given environment is inconsistent from year to year, or for growers who are experimenting with growing in a new locations. For example, a multi-line may include a slightly earlier-maturing variety with a slightly more mold-resistant variety; most other traits are equivalent in each population. The variations in performance of each variety with regard to mold or earliness of maturity ensure that there will be some harvest even in a year where only the early varieties finish (as a result of early rains), or even if mold is more prevalent during the particular grow season. If a grower is new to an area, multi-lines may be useful for the first few years of planting. It is always a shame to plant a single variety, only to find it is not suitable for the particular climate, thus wasting the year of production. The grower may not reap the highest yield as may be possible from a single hybrid variety particularly suited to the climate, but the degree of variation present in multi-lines helps to ensure at least some plants are harvested.

Synthetic variety - an interbreeding population derived from inter-mating a group of specific genotypes, each of which were selected for good combining ability in all possible hybrid combinations. Subsequent maintenance of the

variety is achieved by open pollination and usually involves rounds of recurrent selection over a series of generations.

Intersexuality is a trait that can be expressed due to a multitude of causes, both genetic and environmental. There are intersex plants which are strictly genetic; these plants have inherited a gene that triggers the intersex condition, even given a perfect growing environment. They produce both pistillate and staminate flowers on the same individual under typical environmental conditions. Strict negative selection against these plants is required by breeders and growers in order to eliminate the intersex trait from the breeding population. Cultivators and breeders alike have wisely selected against plants that show the slightest degree of intersexuality. They know even a single male flower on an otherwise female plant can result in the majority of the crop being pollinated, and thus seeded.

Indoors, where growers attempt to mimic Mother Nature, plants often undergo stresses which are not present under natural conditions. When plants are stressed by being grown in an inhospitable environment, the typical expression of characteristics can be altered. Intersexuality, for example, can also be induced in cannabis by a grower's influence as a result of an inconsistent growth environment.

Environmentally stressed female plants have been known to show the occasional male



Intersex plants are often mistakenly called hermaphrodites.



Hermaphrodite plant with both female and male flowers together.

flower. Interrupted dark cycles and other types of stressors can result in the development of staminate flowers on otherwise pistillate individuals. Environmental conditions which may provoke sexual reversal include an inconsistent photoperiod, nutrient toxicities and deficiencies, pH issues, or drastically fluctuating temperatures during the flowering cycle. Females severely stressed, for any reason, are more prone to develop a few male flowers. These stresses cause changes in the levels of a plant hormone called ethylene.

Ethylene is one of only a few known plant hormones, and plays many roles in plant development across a range of species. In cannabis, one of ethylene's major roles is its involvement in the determination of sex. It regulates which flowers should be produced—stamen or pistil.



Applying a hormonal spray is easy.

We know this because applying high enough concentrations of ethylene to staminate individuals in the flowering cycle results in the formation of pistils. Conversely, applying ethylene-inhibiting agents to pistillate individuals as they enter flowering results in the formation of stamens in place of pistils. This practice can be of use to breeders in the creation of "feminized" seeds, or all-female (gynoecious) seedlots.

All female seeds are produced by obtaining pollen from one female individual, and subsequently fertilizing another female plant.

When we previously discussed chromosomes, we said there were 20 chromosomes in each cell

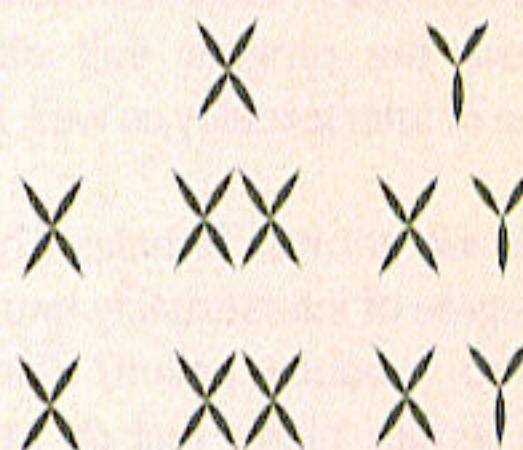
of the plant. The 10th pair of chromosomes, the smallest pair, are the sex chromosomes. Female cannabis plants have two copies of the X chromosome, therefore their genotype is XX. Male plants have only 1 copy of the X chromosome, and a Y chromosome instead of a second X chromosome. The genotype of male plants in terms of the sex chromosomes is XY.

When pollen is created within the plant, one of each of the chromosome pairs is packaged into the cells that develop into pollen. Each pollen grain or ovule contains 10 chromosomes, 1 copy of each pair. When the pollen deposits the genetic material into the ovule, the 10 chromosomes from the pollen and the ovule unite to make a total of 20 chromosomes, a full genetic complement.

Let's examine a Punnet square from a typical male:female cross -

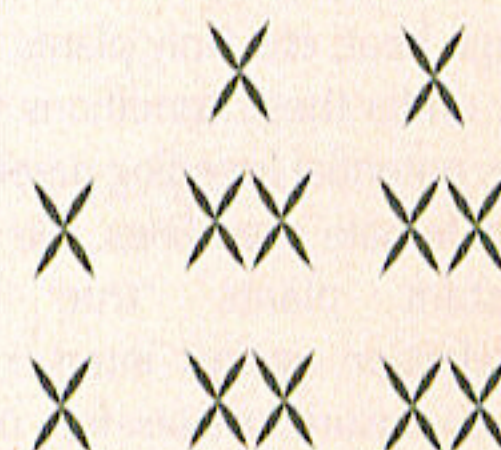
Male genotype = XY

Female genotype = XX



From above we can see that half of the plants are XY (male) and half of the plants are XX (female).

Let's now look at a Punnet square from a female:female cross -



This Punnet square shows us that female:female breeding schemes produce only female (XX) offspring.

Some growers intentionally use the pollen from intersex plants to fertilize females. They have found that the seeds and subsequent offspring produced from this union will be predominately female. The major problem with this technique is that these plants will have intersex tendencies. By selecting parent plants that have intersex tendencies, we ensure that some of the progeny will also have intersex tendencies. Using pollen from an intersex or hermaphrodite plant is an intentional selection for intersexuality—like begets like.

Some seed companies market "feminized seeds," which are produced by collecting pollen from carefully selected, latent, stress-induced hermaphrodites, and use it to pollinate female plants. This process is time consuming and arduous, but yields mostly female plants when grown without stress. However, under the stresses that resulted in the intersexuality for the pollen parent, the progeny will often show some degree of intersexuality as well. Again, like begets like.

So how do we get true females (that do not show any degree of intersexuality under normal conditions) to produce pollen? Can we get pollen from female plants that do not show a degree of intersexuality?

There are hormone treatments, which, when applied to cannabis, result in the formation of staminate flowers on otherwise pistillate plants. To select against the intersex condition, we take our chosen female breeding candidates and grow them under stressful conditions that may lead to the formation of male flowers—irregular light cycle, high heat, etc. Only plants that resist intersexuality under these conditions should be considered as potential breeding parents for the creation of all-female seed lines. We call these intersex-resistant plants "true females." Intentional selection against intersex plants is the only way to ensure intersex-free offspring.

Clone copies of these pistillate intersex-resistant plants are then sprayed with our hormone treatment and placed into the flowering cycle and allowed to develop stamens. It typically takes three to five weeks for the plants to enter dehiscence and shed pollen. True female candidates that also resist intersexuality under typical stresses, are pollinated by pollen obtained by our hormone-treated, gender-reversed, stamen-bearing female plants. The result is a true gynocious population, consisting entirely of female plants.

An American company, Hybritech, was the first to introduce an effective ready-to-use hormone treatment—eliteXelite. This product is no longer available for public purchase. Another plant research firm, PG-Solutions, has since developed and released a ready-to-use hormone therapy spray, Stamen-It!. Stamen-It! is extremely effective in causing gender reversal of pistillate individuals. Some hormone sprays are able to induce staminate flower formation, but fail to produce viable pollen in any significant quantities. PG-Solutions has developed a formulation that causes significant pollen production, even in the most reversal-resistant genotypes. If you are interested in this technology, check their website, www.PGSolutions.com.

Breeding schemes for cross-pollinated crops

There are many types of breeding programs, some more complex than others. Which breeding method to employ depends entirely on the breeder's goal. Ideally, potential breeders understand the benefits and drawbacks of each strategy, so a suitable strategy can be chosen to achieve the desired goal. The breeder's personal preference always comes into play when choosing a breeding program. Previous successes may influence a breeder to use one specific breeding strategy over another. Some breeders rely heavily on science and statistics when analyzing the performance of their hybrids or progeny. Others consider breeding more of an art,

and select based on feeling. Over the course of a breeding program, a breeder will often use more than one method to achieve various aspects of the goal.

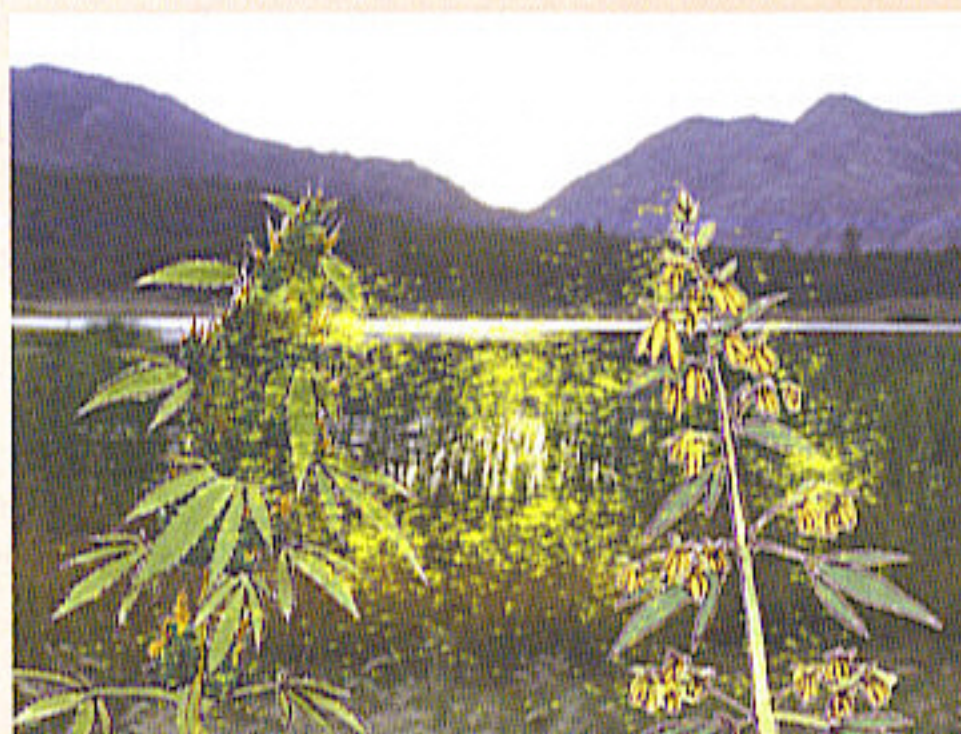
When breeding cross-pollinators, we discuss hybrid performance in terms of combining ability—the ability of an inbred line to give characteristic performance in hybrid combinations with other lines. The progenies are tested for performance as populations and related back to the parental generation. Some often-used measures of performance are general combining ability (GCA) and specific combining ability (SCA). General combining ability is the average or overall performance of a given line in hybrid combinations open-pollinated with other lines.

Specific combining ability is the performance of a specific line, as compared to other lines, when crossed with the same specific pollen source.

Open pollination is a very low effort type of seed production and involves minimal, if any, selection. Seeds are planted, grown to maturity, and allowed to interbreed. Off-types, or plants that do not represent the defining characteristics of the variety, are rogued from the breeding population, to ensure the variety remains pure and true to type. Inbred lines, and other populations maintained through open pollination, are often bred by one person, and then produced for commercial production and release by others. Some breeders create true-breeding populations, then licence them to other companies who plant them and expand the seed populations by growing out many, many plants and allowing them all to fully seed. This is called a seed-increase.

Inbreeding

Inbreeding is nothing more than crossing a group, family, or variety of plants within themselves with no additions of genetic material from an outside or unrelated population. The most severe form of inbreeding is the self-cross, in which only one individual's genetic material forms the basis of subsequent generations. 1:1



A male plant is fertilizing a female.



Inbreeding consists of crossing a group, family, or variety of plants with themselves.

hybrid populations are only slightly less narrow, derived from the genetic material of 2 individuals. Such tight or narrow breeding populations lead to a condition called "inbreeding depression" upon repeated self-breeding or inbreeding.

Inbreeding depression is a reduction in vigor (or any other character) due to prolonged inbreeding. This can manifest as a reduction in potency or a decrease in yield or rate of growth. Progress of depression is dependent, in part, on the breeding system of the crop. Earlier, when we discussed dioecy, we said cannabis is an out-crossing or cross-pollinating species. Cross-pollinated crops usually exhibit a higher degree of inbreeding depression when "selfed," or inbred, than do selfing crops. For example, tomato (an inbreeding or selfing species) can be selfed for 20 generations with no apparent loss in vigor or yield, whereas some experiments have shown that the yield of corn per

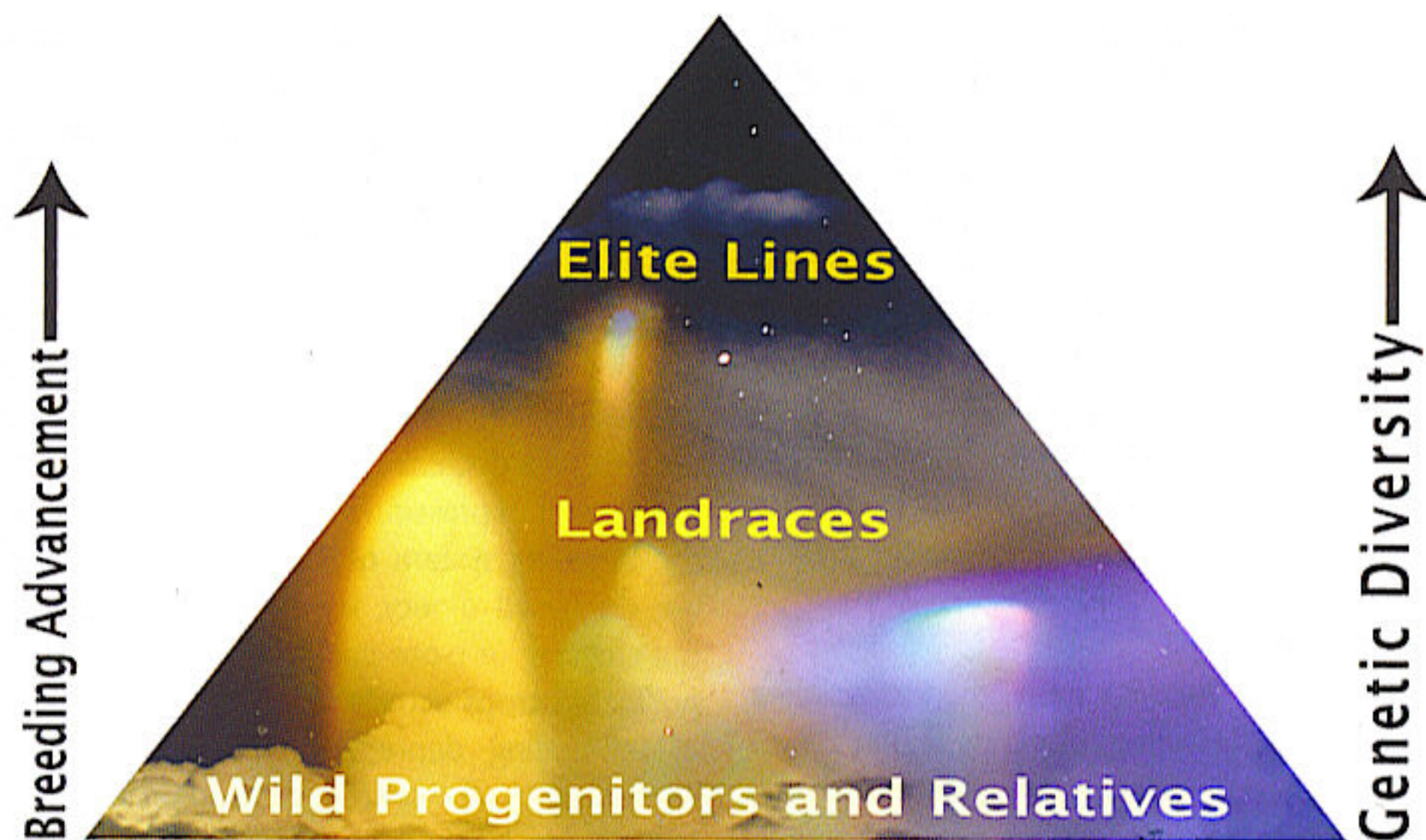
acre is decreased quite dramatically when inbred for 20 generations.

In cross-pollinated crops, deleterious genes remain hidden within populations, and the negative attributes of these recessive traits can be revealed or unmasked via continual inbreeding. Inbreeding depression can be apparent in S1 populations after a single generation of self-fertilization. When breeding cannabis using small populations, as is often the case with continual 1:1 mating schemes, inbreeding depression typically becomes apparent within three to six generations. To deal with this problem, breeders often maintain separate parallel breeding lines, each of which are selected for similar or identical sets of traits. After generations of inbreeding, when each of the inbred lines, or selfed populations, begin to show inbreeding depression, they are hybridized or out-crossed to each other to restore vigor and eliminate inbreeding depression while preserving the genetic stability of the traits under selection.

The vast majority of texts written to date on the subject of breeding cannabis have espoused

1:1 mating strategies, much to the detriment and health of cannabis germplasm. Sadly, this is the preferred breeding scheme used today by the majority of commercial seed banks. These breeders don't realize that cannabis is naturally an out-crossing or cross-pollinating species and existed in wild breeding populations of hundreds if not thousands of individuals. Within these many individuals lies a wide range of versions of different genes. When we select only one or two plants from this vast array as our breeding population, we drastically reduce the genetic variability found in the original population (a genetic bottleneck). This variability is lost from the populations, and unavailable to future generations.

Outbreeding - the process of crossing or hybridizing plants or groups of plants with other plants to which there is no, or only a distant, relation. Any time a breeder is hybridizing using plants that reside outside of the family, group, or variety, hybrid seed is produced. For example, an F1 hybrid seed is the first generation offspring resulting from a cross of two distinct true-



This pyramid shows the evolution of breeding cannabis.

breeding plants or populations. Each of the parent populations were hybridized (out-crossed to each other) to produce the new generation, which is now comprised of genetics from both parental populations. Out-crossing results in the introduction of new and different genetic material to each of the respective pools.

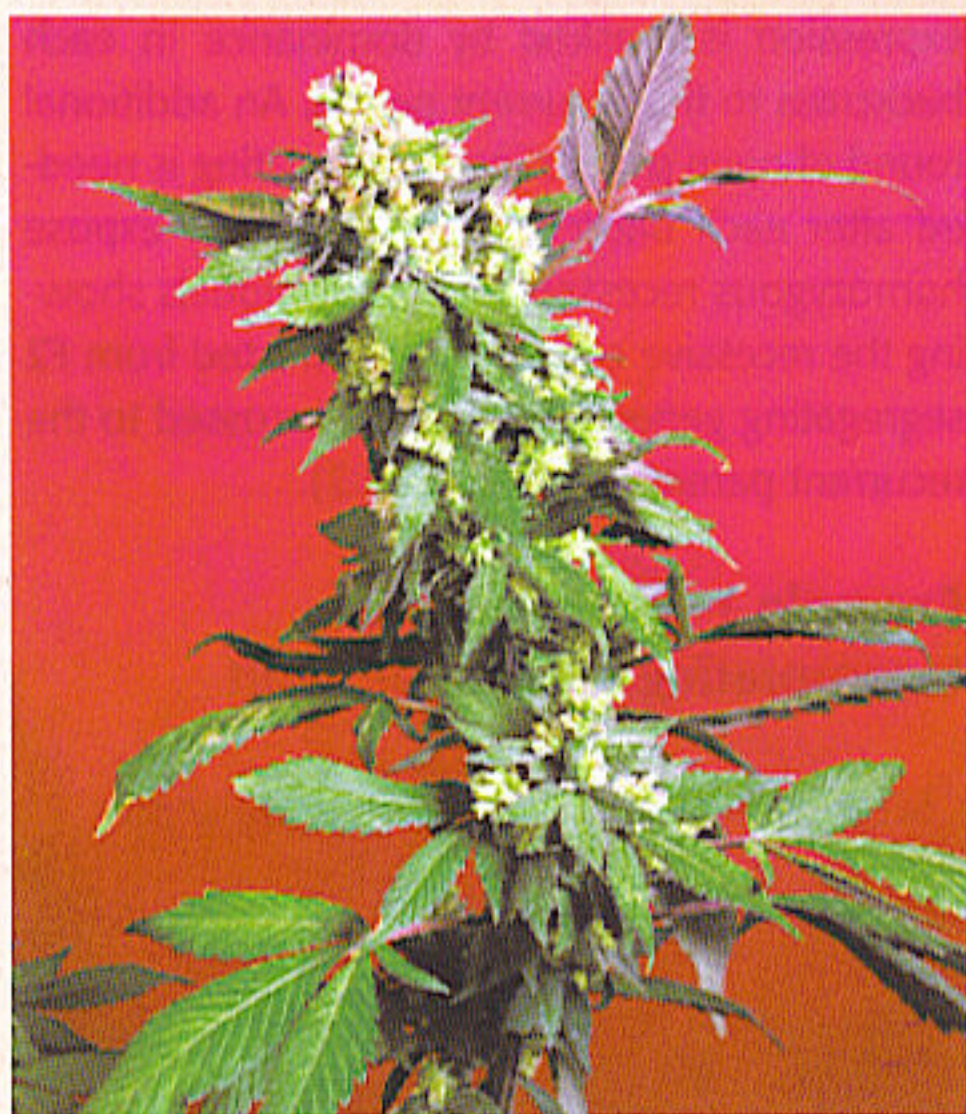
Filial Breeding - A type of breeding system where siblings of the same progeny lot and generation are inter-mated to produce new generations. The first hybrid generation of two distinct true-breeding lines is denoted the F1 generation (F, filial). If two F1 siblings are bred, or the F1 population is allowed to be open pollinated, the resulting generation is labeled F2.

Mating siblings chosen from the F2, results in the F3 population. F4, F5, F6 generations, etc., are obtained in the same manner, by crossing plants of the same generation and progeny lot. Note that as long as any number of siblings of a generation (F[n]) are mated, the resulting generations is denoted (F[n+1]).

Filial inbreeding with selection for specific traits is the most common method for establishing a pure or a true-breeding population, when breeding cross-pollinated species such as cannabis.

Backcross Breeding - A type of breeding that involves repeated crossing of progeny with one of the original parental genotypes; cannabis breeders most often cross progeny to the mother plant. This parent is known as the recurrent parent. The non-recurrent parent is called the donor parent. More widely, any time a generation is crossed to a previous generation, it is a form of backcross breeding. Backcross breeding has become one of the staple methods clandestine cannabis breeders use, mainly because it is a simple, rapid method when using greenhouses or growrooms, and requires only small populations. The principal goal of backcross breeding is to create a population of individuals derived mainly from the genetics of one single parent (the recurrent parent).

The donor parent is chosen based on a trait of



Sprayed with 'Stamen-It!' from PG-Solutions, this plant that started out as a female is now expressing only male flowers.

interest that the recurrent parent lacks; the idea is to introgress this trait into the backcross population, such that the new population is comprised mainly of genetics from the recurrent parent, but also contains the genes responsible for the trait of interest from the donor parent.

The backcross method is a suitable scheme for adding new desirable traits to a mostly ideal, relatively true-breeding genotype. When embarking on a backcross breeding plan, the recurrent parent should be a highly acceptable or nearly ideal genotype (for example, an existing commercial cultivar or inbred line). The ideal traits considered for introgression into the new seed line should be simply inherited and easily scored for phenotype. The best donor parent must possess the desired trait, but should not be seriously deficient in other traits. Backcross line production is repeatable, if the same parents are used.

Backcross breeding is best used when adding simply inherited dominant traits that can easily be identified in the progeny of each generation (Example 1). Recessive traits are more difficult to select for in backcross breeding, since their

expression is masked by dominance in each backcross to the recurrent parent. An additional round of open pollination or sib-mating is needed after each backcross generation, to expose homozygous-recessive plants. Individuals showing the recessive condition are selected from F2 segregating generations and backcrossed to the recurrent parent (see Example 2).

Example 1- Backcrossing: Incorporating a dominant trait

Step1 - Recurrent Parent $\times$ Donor Parent

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v

F1 Hybrid generation

Step 2 - Select desirable plants showing dominant trait, and hybridize selected plants to recurrent parent. The generation produced is denoted BC1 (some cannabis breeders break from botanical convention and denote this generation B $\times$ 1. [BC1= B $\times$ 1]).

Step 3 - Select plants from BC1 and hybridize with the recurrent parent; the resulting generation is denoted BC2.

Step 4 - Select plants from BC2 and hybridize with the recurrent parent; the resulting generation is denoted BC3.

Example 2 Backcrossing: Incorporating a recessive trait

Step1 - Recurrent Parent $\times$ Donor

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F1 Hybrid generation

Step 2 - Select desirable plants, and create an F2 population via full sib-mating.

Step 3 - Select plants showing the desired recessive trait in the F2 generation, then hybridize selected F2-recessive plants to the recurrent parent. The generation produced is denoted BC1.

Step 4 - Select plants from BC1, and create a generation of F2 plants via sib-mating; the resulting generation can be denoted BC1F2.

Step 5 - Select desirable BC1F2 plants showing the recessive condition, and hybridize with the recurrent parent; the resulting generation is denoted BC2.

Step 6 - Select plants from BC2, and create an F2 population via sib-mating; denote the resulting generation BC2F2.

Step 7 - Select plants showing the recessive condition from the BC2F2 generation, and hybridize to the recurrent parent; the resulting generation is denoted BC3.

Step 8 - Grow out BC3, select and sib-mate the most ideal candidates to create an F2 population, where plants showing the recessive condition are then selected and used as a basis for a new inbred, or open-pollinated, seed line.

This new generation created from the F2 is a population that consists of, on average, ~93.7% of genes from the recurrent parent, and only ~6.3% of genes leftover from the donor parent. Most importantly, one should note that since only homozygous-recessives were chosen for mating in the BC3F2 generation, the entire resulting BC3F3 generation is homozygous for the recessive trait, and breeds true for this recessive trait. Our new population meets our breeding objective. It is a population derived mainly from the genetics of the recurrent parent, yet breeds true for our introgressed recessive trait.

Backcross derived lines are expected to be well-adapted to the environment in which they will be grown, which is another reason backcrossing is often used by cannabis breeders who operate indoors. Indoor grow rooms are easily replicated all over the world, so the grower is able to grow the plants in a similar environment in which they were bred. Progeny therefore need less extensive field-testing by the breeder across a wide range of environments.

If two or more characters are to be introgressed into a new seed line, these would usually be tracked in separate backcross programs,

and the individual products would be combined in a final set of crosses after the new populations have been created by backcrossing.

The backcross scheme has specific drawbacks, however. When the recurrent parent is not very true-breeding, the resulting backcross generations segregate, and many of the traits deemed desirable to the line fail to be reproduced reliably. Another limitation of the backcross is that the "improved" variety differs only slightly from the recurrent parent (e.g., one trait). If multiple traits are to be introgressed into the new population, other techniques such as inbreeding or recurrent selection, may be more rewarding.

Selfing

Selfing is the process of creating seed by fertilizing a plant with pollen obtained from itself. The result of a self-cross is a population of plants that derive from a single individual. The first generation population derived from selfing an individual is called the S1 population. If an individual is chosen from the S1, and again selfed, the resulting population is denoted the S2 generation. Subsequent generations derived in the same manner are denoted S3, S4, etc.

Traits for which the plant is homozygous remain homozygous upon selfing, whereas heterozygous loci segregate, and may demonstrate novel expressions of these characters.

We know homozygous loci remain homozygous in future generations upon selfing, but what about the heterozygous loci? Each selfed generation leads to an increase in homozygosity by 50% for each heterozygous locus, and each subsequent generation, derived from selfing an S1 individual, is 50% more homozygous than the parent from which it was derived. Repeated selfing, or single seed descent, is the fastest way to achieve homozygosity within a group or family. Again, the more plants grown from a selfed population, the better probability a breeder has of finding selfed progeny that show all of the desired traits.

Single-seed descent - A plant is self-fertilized and the resulting seed collected. One of these seeds is selected and grown, again self-fertilized, and seed produced. All progeny and future generations have descended from a single ancestor, as long as no pollen from an external family is introduced. Each generation is the result of selfing one individual from the previous generation.

After six generations of selfing without selection, 98.44% of the genes of an individual are homozygous—this refers to genes, not the number of plants that are homozygous.

Recurrent Selection - Any breeding program designed to concentrate favorable genes scattered among a number of individuals by repeated cycles of selection for favorable traits.

Step 1- Identify superior genotypes for the trait under selection.

Step 2 - Inter-mate the superior genotypes and select improved progeny.

Step 3 - Repeat steps 1 & 2 over a series of generations.

Pedigree Selection - A system of breeding in which individual plants are selected in the segregating generations from a cross on the basis of their desirability, judged individually, and on the basis of a pedigree record.

PLOIDY - Cannabis plants are, by nature, diploids with twenty chromosomes. At meiosis, each parent's gamete contributes ten chromosomes to the zygote they have formed. Cannabis cells may be haploid (have 1 copy of each chromosome set) as in gametes, or diploid (2 chromosome sets per cell).

Some researchers have wondered whether triploid, or tetraploid cannabis (cells with either 3 or 4 chromosome sets respectively) are agronomically important. In some species, polyploid plants grow bigger, yield more, or outperform typical diploid members of the same species. Some early reports touted polyploid cannabis as being more more potent. This research was flimsy and unscientific at best, and ever since this report, many cannabis growers have

attempted inducing polyploidy in many varieties, none leading to agronomic success.

Diploid plants are considered normal and have one set of chromosomes, which occur in pairs within each plant cell. Polyploid plants have more than one set of chromosomes per cell. Polyploid plant chromosomes occur in groups of 3-4 instead of in pairs. Tetraploid plants groups occur with four chromosomes in each cell.

At one time, breeders believed that polyploid and tetraploid plants would produce a superior resin-packed plant.

The polyploid characteristic can be induced with an application of colchicine. Just remember, colchicine is a poison, and polyploid plants do not contain more THC-potent resin.

Mutagenesis—Inducing Variation

If variation does not exist for the trait or traits of interest, or cannot be found in other populations, it is theoretically possible to induce variation by exposing seeds or other tissues to radiation, alkylating agents, or other mutagens such as colchicine or EMS (ethylmethylsulfonate). These treatments cause changes at the DNA level that have the remote potential to result in desirable, novel phenotypes.

There is much rumour and speculation about this technique amongst breeders and growers. It's a common myth that treating seeds with colchicine and growing the plants results in more potent cannabis plants. Let's put this myth to rest; it is completely untrue. While the possibility does exist on a theoretical level, no valid experiments have ever shown this to be true. Potential breeders would be better off using their time and space for selecting better plants than trying this technique as a method for improving plant stock.

That being said, let's take a look at the theory behind the concept.

Imagine you have a population of plants which, when grown from seed and inbred within the population, consistently produces high-

THC plants. It is theoretically possible to treat many of these seeds with a mutagen, grow and inbreed the seeds, and find plants in subsequent generations that produce no THC. These mutagens can destroy genes along a chromosome, and when copies of this chromosome are inherited by future generations, a new or "novel" phenotype can appear. In our example, the no THC condition is the novel phenotype.

These mutations, however, occur at random and are extremely unreliable. The probability of finding plants which have a desired mutation in the gene of interest is very low. A breeder may treat many thousands of seeds, grow 100,000 plants, and still not see the desired altered phenotypes. This technique is costly in both time and space. It is often used in the breeding of "legal plants" when growing out thousands of individuals and searching for these novel phenotypes is not problematic. Performing such population screens in cannabis is not practical, especially for clandestine breeders. The potentially hazardous nature of these mutagenic agents is another very good reason to choose other breeding options. Inducing variability is likely not the best option, at least for the hobby breeder.

If you are serious about breeding cannabis, check out *Marijuana Botany, An Advanced Study: The Propagation and Breeding of Distinctive Cannabis*, by Robert Connell Clarke, Ronin Press. Using understandable scientific detail, Clarke discusses genetics and breeding, chemistry, and much more of interest to the budding breeder. This book is worth its weight in 'Haze' buds. If you can't find it at the bookstore, check out our web site: www.marijuana-growing.com or order via our TOLL FREE number 1-877-989-4800, or 1-360-837-3368.



Conversion Charts and Tables

Carbon Dioxide Facts and Figures

molecular weight = 44 grams/mole

sublimes (solid to gas) at 78.5°C at 1 atmosphere - air density = 1.2928 grams/liter (i.e., at equal temperatures and pressures carbon dioxide is heavier than air, and CO₂ will fall to the bottom of an air/ CO₂ mixture.

psi = 1 atmosphere

Physical properties of Propane:

specific gravity of gas (air = 1)	1.50
pounds per gallon of liquid @ 60°F (15°C)	4.23
gallons per pound of liquid @ 60°F (15°C)	0.236
Btu per cubic foot of gas @ 60°F (15°C)	2488
Btu per pound of gas	21548
Btu per gallon of gas @ 60°F	90502
cubic feet of gas per gallon of liquid	36.38
octane number	100+

Combustion Data:

cubic feet of air to burn 1 gallon of propane	873.6
cubic feet of CO ₂ per gallon of Propane burned	109.2
cubic feet of nitrogen per gallon of propane burned	688
pounds of CO ₂ per gallon of propane burned	12.7
pounds of nitrogen per gallon of propane burned	51.2
pounds of water vapor per gallon of propane burned	6.8
1 pound of propane produces in kWh	6.3
Btu's per kW hour	3412

1 Therm	100,000 Btu	Specific gravity of liquid	0.509
1 cubic foot natural gas	1000 Btu	Vapor pressure (psig) 00F	23.5
1 pound steam	970 Btu	Vapor pressure (psig) 700 F	109
1 kilowatt	3413 Btu	Vapor pressure (psig) 1000 F	172

Calculations for Metric Users

1 cubic meter = 1 m × 1 m × 1 m = 1000 liters
fans are rated at liters per minute or liters per second

cubic feet = L × W × H
cubic meters = L × W × H

Buy a fan that will clear the grow room volume of air in one to five minutes. Run the fan for twice the time to theoretically clear the grow room of air.

Work out the amount of CO₂ gas to add:

For example, if you want 1500 ppm and ambient CO₂ is 350 ppm, you will need to add: 1500 ppm minus 350 ppm = 1150 ppm CO₂.

A poorly sealed grow room can have 20 per cent leakage which should be added to the amount of CO₂ required.

For example, to get the desired 1500 ppm of CO₂ for a grow room with 21.6 cubic meters, add: $21.4 \times 1150 = 24.61 \text{ liters} \times 1.2 = 29.53 \text{ liters}$.

This information tells you to set the flow meter to 6 liters per minute and run the gas for 5 minutes.

Leave the gas-enriched air for 20 minutes and exhaust the air from the garden room.

Metric Conversion Chart -

Approximations

When You Know Multiply by To Find

Length

millimeters	0.04	inches
centimeters	0.39	inches
meters	3.28	feet
kilometers	0.62	miles
inches	25.40	millimeters
inches	2.54	centimeters
feet	30.48	centimeters
yards	0.91	meters
miles	1.16	kilometers

Area

sq. centimeters	0.16	square inches
square meters	1.20	square yards
square kilometers	0.39	square miles
hectares	2.47	acres
sq. inches	6.45	sq. centimeters
square feet	0.09	square meters
square yards	0.84	square meters
square miles	2.60	sq. kilometers
acres	0.40	hectares

Volume

milliliters	0.20	teaspoons
milliliters	0.60	tablespoons
milliliters	0.03	fluid ounces
liters	4.23	cups
liters	2.12	pints

liters	1.06	quarts
liters	0.26	gallons
cubic meters	35.32	cubic feet
cubic meters	1.35	cubic yards
teaspoons	4.93	milliliters
tablespoons	14.78	milliliters
fluid ounces	29.57	milliliters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.790	liters

Mass and Weight

1 gram	= 0.035 ounces
1 kilogram	= 2.21 pounds
1 ounce	= 28.35 grams
1 pound	= 0.45 kilograms

1 inch (in)	= 25.4 millimeters (mm)
1 foot (12 in)	= 0.3048 meters (m)
1 yard (3 ft)	= 0.9144 meters
1 mile	= 1.60937 kilometers
1 square inch	= 645.16 square millimeters
1 square foot	= 0.0929 square meters
1 square yard	= 0.8361 square meters
1 square mile	= 2.59 square kilometers

Liquid Measure Conversion

1 pint (UK)	= 0.56826 liters
1 pint dry (USA)	= 0.55059 liters
1 pint liquid (USA)	= 0.47318 liters
1 gallon (UK) (8 pints)	= 4.5459 liters
1 gallon dry (USA)	= 4.4047 liters
1 gallon liquid (USA)	= 3.7853 liters

1 ounce	= 28.3495 grams
1 pound (16 ounces)	= 0.453592 kilograms

1 gram	= 15.4325 grains
1 kilogram	= 2.2046223 pounds
1 millimeter	= 0.03937014 inches (UK)
1 millimeter	= 0.03937 inches (USA)
1 centimeter	= 0.3937014 inches (UK)
1 centimeter	= 0.3937 inches (USA)
1 meter	= 3.280845 feet (UK)
1 meter	= 3.280833 feet (USA)
1 kilometer	= 0.6213722 miles
1 cm	= 0.001 meter

mm = 0.0001 meter
 nm = 0.000 000 001 meter
 gm = grams
 sq = squared
 EC = electrical conductivity
 ppm = parts per million
 Celsius to Fahrenheit
 Celsius temperature = $(^{\circ}\text{F} - 32) \times 0.55$
 Fahrenheit temperature = $(^{\circ}\text{C} \times 1.8) + 32$

Light Conversion

1 foot-candle = 10.76 = lux
 1 lux = 0.09293

lux = 1 lumen/square meters
 lumens per square foot = lumens per meter squared

cfm (cubic feet per minute) = liters per hour
 Inches of rain = liters per meter squared
 psi (pounds per square inch) = kg per square meter

1 liter = 1 kg (of pure water)
 1 kilometer = 1000 meters
 1 meter = 100 centimeters
 1 meter = 1000 millimeters

Cannabis Seed Companies

Many companies were not included in this abridged list because they do not have catalogs and were too difficult to contact.

Almighty Seeds



www.almightyseeds.com

BC Bud Depot

No catalog
www.bcbudonline.com

Black Label Seeds



www.highquality-seeds.nl

British Colombia Seed Co.

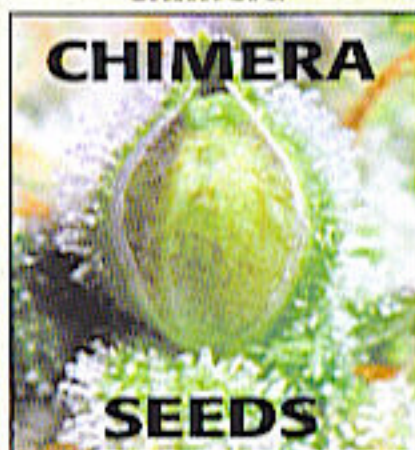
No catalog
www.thebcsc.com

CannaBiogen



www.cannabiogen.com

Chimera



DJ Short

No catalog.
 No website

Dutch Passion



www.dutch-passion.nl

Flying Dutchmen



www.flyingdutchmen.com

Good House Seeds



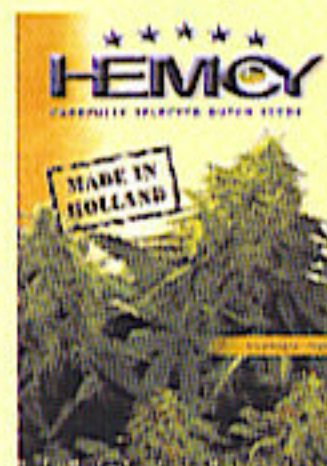
www.goodhouseseeds.com

Greenhouse



www.greenhouseseeds.nl

Hemcy



www.hemcy.com

High Quality Seeds



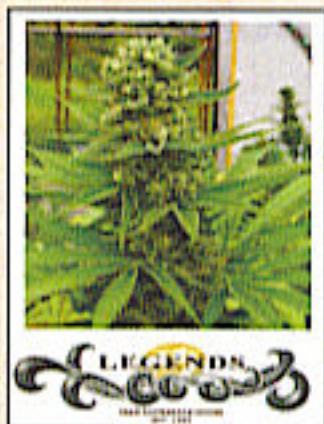
www.highqualityseeds.nl

Homegrown Fantaseeds



www.homegrownfantaseeds.com

Legend Seeds



www.legendsseeds.com

Magus Genetics



www.magusgenetics.com

Mandala Seeds



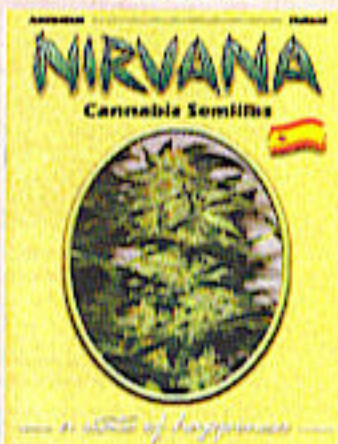
www.mandalaseeds.com

Mr. Nice-Swiss



www.mrnice.co.uk

Nirvana



www.nirvana.nl

No Mercy Supply

No catalog
www.nomercy.nl

Owl's Production



Website: None

Paradise Seeds



www.paradise-seeds.com

Reeferman Seeds



www.reefermanseeds.com

Sagarmatha

www.highestseeds.com

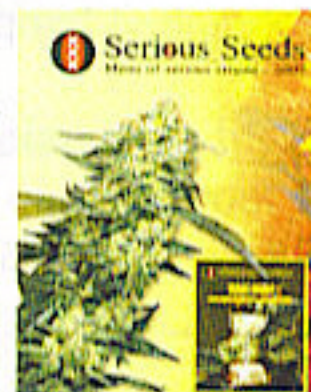


Sensi Seeds

www.sensiseeds.com

Serious Seeds

www.seriousseeds.com



Soma Seeds - No catalog

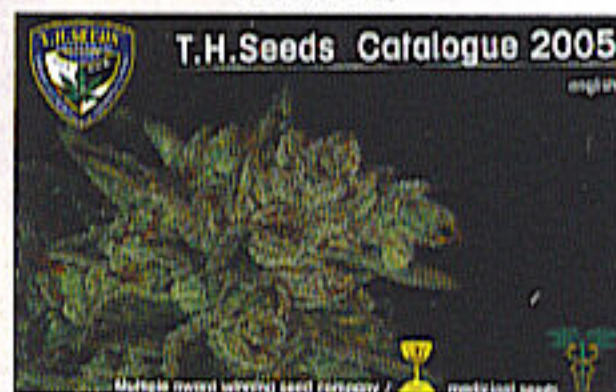
www.somaseeds.nl



Spice of Life

www.spiceoflife.com

THSeeds



www.thseeds.com

Valchanvre



www.valchanvre.ch

Willy Jack

No catalog
www.willyjack.com

World Wide Seeds

No catalog
www.worldwideseeds.com

Glossary

absorb: to draw or take in: Rootlets absorb water and nutrients.

AC (alternating current): an electric current that reverses its direction at regularly occurring intervals: Homes have AC.

acid: a sour substance: An acid or sour soil has a low pH.

active: a hydroponic system that actively moves the nutrient solution

adobe: heavy clay soil that drains slowly: Adobe is not suitable for container gardening.

aeration: to supply soil and roots with air or oxygen

adventitious roots: roots that grow from unusual spots, as on the (stem) pericycle or endodermis of an older root. Auxin level may influence this type of root growth.

aeroponics: growing plants by misting roots suspended in air

aggregate: a substrate that is of nearly uniform size and used for the inert hydroponic medium

agronomically: having to do with the economics of agriculture

alkaline: refers to soil, or any substance, with a pH over 7

alkylation: a process in which an alkyl group is substituted or added to a compound

alleles: two genes, each of which occupies the same position or locus on two homogenous chromosomes

amendments: can be either organic or mineral based: Amendments change the texture of a growing medium.

ampere (amp): the unit used to measure the strength of an electric current: A 20-ampere circuit is overloaded when drawing more than 16 amps.



Adventitious roots

androecious: a plant having staminate (MALE) flowers: An androecious population consists of only males, sometimes called all-male.

anemophilous: pollinated by wind-dispersed pollen

annual: a plant that normally completes its entire life cycle in one year or less: Cannabis is an annual.

arc tube: container for luminous gases; houses the arc in an HID lamp.

asexual propagation: reproducing using non-sexual means such as taking cuttings from a parent plant: will produce exact genetic replicas of the parent plant

auxin: classification of plant hormones: Auxins are responsible for foliage and root elongation.

bacteria: very small, one-celled plants that have no chlorophyll

bag seed: the common term given seed of unknown origin that was found in a bag of cannabis

ballast: a stabilizing unit that regulates the flow of electricity and starts an HID lamp: A ballast consists of a transformer and a capacitor.

beneficial insect: a good insect that eats bad, marijuana-munching insects

biodegradable: to decompose through natural bacterial action. Substances made of organic matter can be broken down naturally.

biosynthesis: the production of a chemical compound by a plant

bleach: household laundry bleach is used in a mild water solution to sterilize grow rooms and as soil fungicide

blood meal: high-nitrogen organic fertilizer made from dried blood: Dogs love blood meal!

bloom: to yield flowers

blossom booster: fertilizer high in phosphorus and potassium that increases flower yield and weight

bonsai: a very short or dwarfed plant

bract: small spur-like foliage that grows from the stem at the point from which flowers emerge

breaker box: electrical circuit box having on/off switches rather than fuses: The main breaker box is also called a "service panel."

breed: to sexually propagate cannabis under controlled circumstances

bud: 1. a small, undeveloped stem or shoot. 2. a collection of (flowering) calyxes on a branch

bud blight:: a withering condition that attacks flower buds

buffer: a substance that reduces the shock and cushions against fluctuations: Many fertilizers contain buffer agents.

bulb: outer glass envelope or jacket that protects the arc tube of an HID lamp

bulbous trichome: ball-shaped, resin-producing plant hair without a stalk

callus: tissue made of undifferentiated cells produced by rooting hormones on plant cuttings

calyx: the pod harboring male or female cannabis reproductive organs

cambium: layer of cells which divides and differentiates into xylem and phloem and is responsible for growth

Cannabaceae: scientific family to which Cannabis (marijuana) and Humulus (hops) belong

cannabinoid: a hydrocarbon unique to cannabis

cannabinoid profile: proportional ratio and levels of major cannabinoids found in cannabis being tested

Cannabis: scientific name for marijuana specifying genus

capitate stalked trichome: resin-producing plant hair without a stalk, high in THC content

carbohydrate: neutral compound of carbon, hydrogen, and oxygen, mostly formed by

green plants: Sugar, starch, and cellulose are carbohydrates.

carbon dioxide (CO₂): a colorless, odorless, tasteless gas in the air; necessary for plant life

caustic: a substance that destroys, kills, or eats away by chemical activity

CBD: cannabidiol: CBD usually prolongs the high.

CBC - cannabichromene: second most abundant cannabinoid in drug-type cannabis

CBD - cannabidiol

CBDV - cannabidivertol

CBG - cannabigerol

CBN - cannabinol

CBNV - cannabivertol

CBT - cannabitol

CCY - cannabicyclol

cell: the base structural unit of plants: cells contain a nucleus, membrane, and chloroplasts

cellulose: a complex carbohydrate that stiffens a

plant: Outdoor stems contain more stiff cellulose than plants grown indoors.

centigrade: a scale for measuring temperature where 100 degrees is the boiling point of water, and 0 degrees is the freezing point of water

cfm: cubic feet per minute; measures air velocity. Ventilation or extraction fans are measured in the cfm of air they can move.

chelate: combining nutrients in an atomic ring that is easy for plant to absorb

chimera (also chimaera): 1. a plant or organism with tissues from at least two genetically distinct parents 2. A fire-breathing female monster most often portrayed as a lion, goat, and serpent composite.

chlorophyll: the green photosynthetic matter



Callus



Outdoor Plant



Indoor Plant

of plants: Chlorophyll is found in the chloroplasts of a cell and is necessary to photosynthesis.



Chlorosis

chlorosis: the condition of a sick plant with yellowing leaves due to inadequate formation of chlorophyll: Chlorosis is caused by a nutrient deficiency, often iron or imbalanced pH.

chromosomes: microscopically small, dark-staining bodies visible in the nucleus of a cell at the time of nuclear cell division; the number in any species is usually constant. Chromosomes contain the genetic material of a species. Cannabis has 10 pairs of chromosomes.

circuit: a circular route traveled by electricity from a power source, through an outlet, and back to ground

clay: soil made of very fine organic and mineral particles: Clay drains slowly and is not suitable for container gardening.

climate: the average condition of the weather in a grow room or outdoors

clone: 1. a rooted cutting of a plant 2. asexual propagation

CO₂ enrichment: used to augment grow room or greenhouse atmosphere to speed growth



Cola

cola: Mexican and North American slang word for a marijuana flower top: Cola in Spanish actually means tail.

colchicine: poisonous alkaloid from the autumn crocus, used in plant breeding to induce polyploid mutations

cold: for cannabis, air temperatures below 50°F (10°C)

cold frame: an unheated outdoor structure usually clad in glass or clear plastic, used to protect and acclimatize seedlings and plants

color spectrum: the band of colors (measured in nm) emitted by a light source

color tracer: a coloring agent that is added to many commercial fertilizers so the horticulturist knows there is fertilizer in the solution: Peters has a blue color tracer.

compaction: soil condition that results from tightly packed soil which limits aeration and root penetration

companion planting: planting garlic, marigolds, etc., along with cannabis to discourage pests

compost: mixture of decayed organic matter, high in nutrients: Compost must be well-rotted before use. When too young, decomposition uses nitrogen; after sufficient decomposition, compost releases nitrogen.

core: the transformer in the ballast is often referred to as a core

cotyledon: seed leaves, first leaves that appear on a plant

creeper: marijuana high in CBD having psychoactive qualities that sneak up on smoker: The creeper high usually lasts longer.

critical daylength: maximum daylength which will bring about flowering in cannabis

cross-pollination: fertilizing a plant with pollen from an unrelated individual of the same species

crystal: 1. appearance resin has when found on foliage 2. fertilizers often come in soluble crystals

cubic foot: volume measurement in feet: width × length × height = cubic feet

cultivar: a contraction of "cultivated variety," a variety of plant that has been intentionally created or selected; not naturally occurring

cure: 1. slow drying process that makes marijuana more pleasant and palatable to smoke 2. to make a sick plant healthy

cuticle: thin layer of plant wax (cutin) on the surface of the aboveground parts of plants

cutting: 1. growing-tip cut from a parent plant for asexual propagation 2. clone 3. slip
cytokinins: plant hormones that promote cell division and growth and delay the aging of leaves

damping-off: fungus disease that attacks young seedlings and clones causing stem to rot at base: Over-watering is the main cause of damping-off.

DC (direct current): a continuous electric current that only flows in one direction

decompose: to rot or decay, etc., through organic chemical change

dehumidify: to remove moisture from air

dehydrate: to remove water from foliage

deplete: to exhaust soil of nutrients, making it infertile: Once a soil is used to grow a container crop, it is depleted.

desiccate: to cause to dry up: Insecticidal soap desiccates its victims.

detergent: liquid soap concentrate used: 1. as a wetting agent for sprays and water 2. pesticide, Note: detergent must be totally organic to be safe for plants.

diapause: A period of plant dormancy during which growth or development is suspended or diminished

dioecy: a condition where separate sexes occur on separate individuals; each plant displays a single gender

dioecious: a population consisting of gynoeceous and androecious plants

disease: sickness of any kind

dose: amount of fertilizer, insecticide, etc., given to a plant, usually in a water solution

double potting: a two-pot transplanting technique that minimizes root disturbance

drainage: to empty soil of excess water. Good drainage: water passes through soil, evenly promoting plant growth. Bad drainage: drainage water stands in soil, actually drowning roots.

drip (irrigation) system: efficient watering system that employs a main hose with small water emitters (tiny holes) which meter out

water one drop at a time at regular, frequent intervals

drip line: a line around a plant directly under its outermost branch tips: Roots seldom grow beyond the drip line.

dry ice: cold, white, solid substance formed when CO₂ is compressed and cooled: Dry ice

changes into CO₂ gas at room temperatures.
dry soil pocket: small portion of soil that remains dry after watering: Dry soil pockets may be remedied by adding a wetting agent (soap) to water and/or waiting 15 minutes between waterings.

dry well: drain hole filled with rocks, to receive drainage water

electrode: a solid electric conductor used to establish electrical arc between contacts at either end of an HID lamp

elongate: to grow in length: Cannabis stretches from three inches to a foot when flowering is induced.

embolism: bubble of air in the transpiration stream of a cutting; blocks uptake of water and nutrients

emit: to give off, send out (as light or sound, etc.)

embryo: a young plant, developing within the seed: In cannabis, an embryo is derived from a fertilized ovule.

Encarsia formosa: a parasitic wasp that preys on whiteflies

envelope: outer protective bulb or jacket of a lamp

Epsom salts: hydrated magnesium sulfate in the form of white crystalline salt: Epsom salts add magnesium to soil.

equinox: when sun crosses the equator and



The drip line.

day and night are each 12 hours long: The equinox happens twice a year.

essential oils: volatile oils that give plants their

characteristic odor or flavor; contained in the secreted resins of plants

ethane methyl sulfonate: a mutagenic chemical that causes changes at the DNA level; induces genetic mutations

etiolation: growth of a plant in total darkness to increase the chances of root initiation

F1: first filial generation, the offspring of two P1 (parent) plants

F1 hybrid: heterozygous first filial generation

F2: second filial generation, resulting from a cross between two F1 plants

fan leaves: large, fan-like marijuana leaves: Fan leaves are usually low in potency.

female: pistillate, ovule, seed producing

fertilize: 1. to apply fertilizer (nutrients) to roots and foliage 2. to impregnate (unite) male pollen with female plant ovary

fertilizer burn: overfertilization; first, leaf tips burn (turn brown), then leaves curl

FIM pruning: acronym for "Fuck, I missed!" pruning made popular on www.overgrow.com

flat: a shallow container used to start seedlings or clones

flower: blossom, a mass of calyxes on a stem, top, or bud

foliage: the leaves, or

more generally, the green part of a plant

foliar feed: misting fertilizer solution, which is absorbed by the foliage



Etiolation



Flat of clones.

foot-candle (fc): one fc is equal to the amount of light that falls on one square foot of surface located one foot away from one candle
fritted: to fuse or embed nutrients with a glass compound: Fritted Trace Elements (FTE) are long lasting and do not easily leach out of substrate.

fungicide: product that destroys or inhibits fungus

fungistat: product that inhibits fungus

fungus: a lower plant (lacking chlorophyll) that may attack green plants: Mold, rust, mildew, mushrooms, and bacteria are fungi.

fuse: an electrical safety device made of a metal that melts and interrupts the circuit when overloaded

fuse box: electrical circuit box containing circuits controlled by fuses

ganja: slang term for cannabis, from the Indian (Hindustani) word for marijuana

gametes: a reproductive cell specialized for fertilization, having the haploid number of chromosomes: a mature pollen grain or ovule capable of fusing with a gamete of the opposite sex to produce the embryo

gene: part of a chromosome that influences the development and the potency of a plant: Genes are inherited through sexual propagation.

gene pool: collection of possible gene combinations in an available population

genetic makeup: the genes inherited from parent plants: Genetic makeup is the most important factor dictating vigor and potency.

genotype: specific genetic makeup of an individual, which determines the physical appearance of that individual

germplasm: the sum total of the genetic or hereditary materials in a species

gibberellin: a class of plant growth hormone used to promote stem elongation: Gibberellic acid is a form of gibberellin.

girdling: removing a strip of bark or crushing the stem of a plant. Girdling limits the flow of nutrients, water, and plant products, which

can kill the plant.

glandular trichome: plant hair gland which secretes resin

gpm: gallons per minute

green lacewing: insect that preys on aphids, thrips, whiteflies, etc. and their larva and offspring

greenhouse: a heated structure with transparent/translucent walls and ceiling which offer some environmental control to promote plant growth

guano: dung from birds, high in organic nutrients: Seabird guano is noted for being high in nitrogen, and bat guano is high in phosphorus.

gynoecious: an individual plant having all pistillate flowers: in reference to a population, all-female

gynoecium: female part of a flower that consists of one or more pistils

halide: binary chemical compound of a halogen(s) with an electropositive element(s)

halogen: any of the non-metallic elements fluorine, chlorine, bromine, iodine, and astatine existing in a free state: Halogens are enclosed within the arc tube of a metal halide lamp.

hardening-off: gradual adaptation of indoor or greenhouse plants to an outside environment

hashish/hash: a psychoactive drug formed of compressed resin heads of glandular trichomes shaken, washed, or rubbed from cannabis foliage

hash oil: solution of tetrahydrocannabinol with a high THC content; made from cannabis

hemp: fibrous cannabis low in THC, used to make a menagerie of products from textiles to automobiles



Girdling

hermaphrodite: an individual having flowers of both sexes on the same plant. Hermaphrodites are more correctly referred to as "intersex."

Hertz (Hz): a unit of a frequency that cycles one time each second: A home with a 60 hertz AC current cycles 60 times per second.

heterosis: hybrid vigor such that an F1 hybrid falls outside the performance range of the parents with respect to some character or characters: usually applied to size, rate of growth, or general vigor

heterozygous loci: regions along homologous chromosome that have different alleles

HID: High Intensity Discharge lamp: This is the type of lamp used in many indoor grow rooms.

homologous chromosomes: members of paired chromosomes in non-gametic cells; homologous chromosomes are similar in size, shape, and, supposedly, in function. One of each of the homologous chromosomal pair is derived from the male parent, the other from the female.

honeydew: a sticky honey-like substance secreted onto foliage by aphids, scale, and mealy bugs

hood: the reflective cover of a lamp

HOR: the abbreviation stamped on some HID bulbs meaning they may be burned in a horizontal position

hormone: chemical substance that controls the growth and development of a plant: Root-inducing hormones help clones root.

horticulture: the science and art of cultivating plants

hose bib: water outlet usually found outdoors that contains an on/off valve

hostile environment: environment that is unfriendly and inhospitable to pests and diseases

humidity, relative: ratio between the amount of moisture in the air and the greatest amount of moisture the air could hold at the same temperature

humus: dark, fertile, partially decomposed plant or animal matter: Humus forms the organic portion of the soil.

hybrid: an offspring from two plants of different breeds, variety, or genetic make-up

hybrid vigor: greater strength and health or faster rate of growth in the offspring resulting from the cross-breeding of two gene pools

hybridizing: see cross-pollination

hydrogen: light, colorless, odorless, highly flammable gas: Hydrogen combines with oxygen to form water.

hydroponics: growing plants in nutrient solutions without soil, usually in an inert soilless mix

hygrometer:

instrument for measuring relative humidity in the atmosphere: A hygrometer will save time, frustration, and money.

IAA: Indoleacetic acid, a

plant hormone that stimulates growth

IBL: inbred line



Hybrid vigor.



Inductive photoperiod 12 hours day/night.

inbreeding: the process of breeding solely within the seed lot with no external pollen inputs

induce: to effect, cause, or influence via stimulation: A 12-hour photoperiod stimulates flowering.

inductive photoperiod: daylength required to stimulate flowering

inert: a substance that will not chemically react. Inert growing mediums make it easy to control the chemistry of the nutrient solution.

inflorescence: a cluster of flowers

insecticide: a product that kills or inhibits insects

intensity: the amount or strength of light energy per unit or area: Intensity decreases the further away from the source.

intersex: a single individual expressing both staminate and pistillate flowers

intersexual: having sexual characteristics of both the typical male and typical female plants

introgress: to incorporate or add a trait to a given population, without otherwise altering the significant characteristic of the population

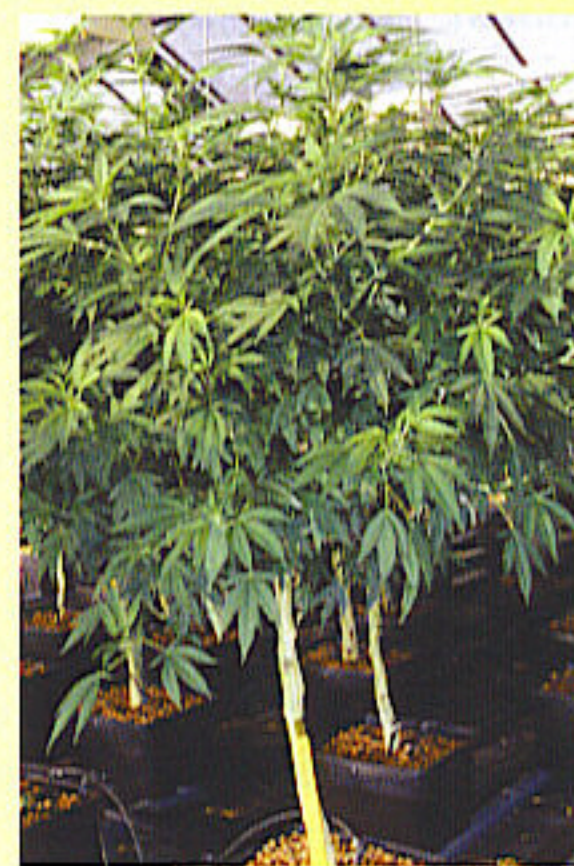
jacket: protective outer bulb or envelope of lamp

kif: Moroccan word for cannabis plants and flowers. It is also the Moroccan term for a mix of tobacco and cannabis which is smoked. Kif does not mean Moroccan hash.

Kilowatt hour (kWh): measure of electricity used per hour: A 1000-watt HID uses one kilowatt per hour.

landrace: is a (wild) cannabis variety that is not improved by humans

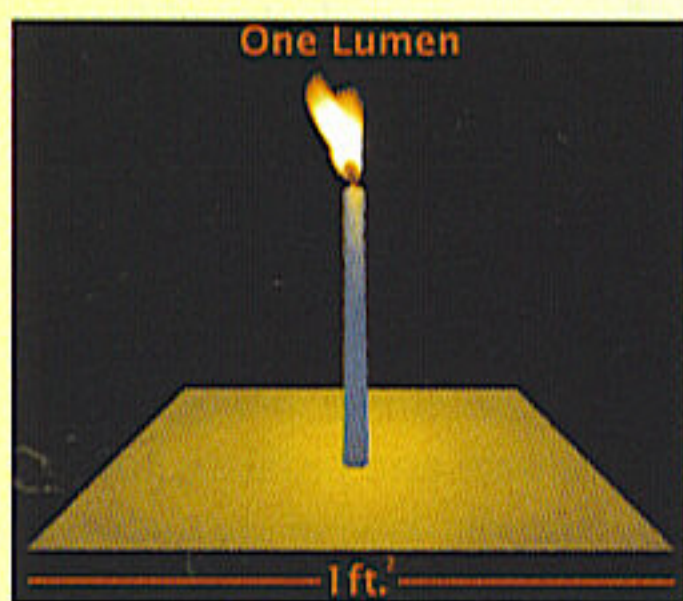
leach: to dissolve or wash out sol-



Limbing

uble components of soil by heavy watering
 leader: see meristem
 leggy: plant that is abnormally tall, with few leaves: usually caused by lack of light
 life cycle: a series of growth stages through which cannabis must pass in its natural life-time: The stages are seed, seedling, vegetative, and floral.
 light mover: a device that moves a lamp back and forth or in a circular path across the ceiling of a grow room to provide more balanced light

limbing:
 cutting off lower, secondary plant branches to encourage primary growth



lime: calcium compounds such as dolomite or hydrated lime that determine or alter soil pH level

litmus paper: chemically sensitive paper used to indicate pH levels in colorless liquids

loam: organic soil mixture of crumbly clay, silt, and sand

locus: a position on a chromosome where a specific gene is located. Plural: loci

lumen: measurement of light output: One lumen is equal to the amount of light emitted by one candle that falls on one square foot of surface located one foot away from one candle.

macronutrient: one or all of the primary nutrients N-P-K (nitrogen, phosphorus, or potassium) or the secondary nutrients Mg (magnesium) and Ca (calcium)

manicure: trim leaves and large stems from buds with scissors or fine pruners so the most THC-potent portion remains

marijuana: cannabis; illegal drug in many countries, ingested for its THC content

meristem: leader: plant tissue from which new cells are formed; the active growing tip of a root or stem

meristem pruning: cutting away the growth tip to encourage branching and limit height

micron: one-millionth of a meter. The symbol " μ " is used to denote micron.

micronutrients: trace elements necessary for plant health, including S, Fe, Mn, B, Mb, Zn, and Cu

millimeter: 0.04 inch

mist: to manufacture rain with the help of a spray bottle

moisture meter: electronic device that measures the moisture content of a substrate at any given point

monoecious: having male and female reproductive systems or flowers on the same plant

monoecious: an individual plant having both staminate and pistillate flowers. A monoecious population consists of plants expressing flowers of both genders.

monochromatic: producing only one color: LP sodium lamps are monochromatic.

morphology: the study of the form and structure of animals and plants

Mother Nature: the vast outdoors and all she holds: The indoor horticulturist assumes the role of Mother Nature.

mother plant: female marijuana plant held in vegetative state and used for cutting (cloning) stock: A mother plant may be grown from seed or be a clone.

mulch: a protective covering for the soil of compost, old leaves, paper, rocks, etc.: Indoors, mulch keeps soil too moist and possible fungus



Necrosis

could result. Outdoors, mulch helps soil retain and attract moisture.

mutation: an inheritable change in genetic material

mycelium: the mass of strands that form the root-like part of fungi, often submerged in soil or a host body

nanometer (nm):

0.00000001

meter, one billionth

of a meter, nm is

used as a scale to

measure electromagnetic wavelengths of light: Color and light spectrums are expressed in nanometers.

necrosis/necrotic: localized death of a plant part due to injury or disease

nitrogen (N): essential element to plant growth; one of the three major nutrients N-P-K

node: a joint: the position on a stem from which leaves, shoots, or flowers grow

N-P-K: nitrogen, phosphorus, and potassium: the three major plant nutrients

nursery: gardening business that grows plants for sale or experimentation: A nursery is a great place to gather information.

nutrient: plant food, essential elements N-P-K as well as secondary and trace elements fundamental to sustaining plant life

Ohms Power Law: a law that expresses the strength of an electric current: Volts $\times$ Amperes = Watts.

open pollination: pollination that occurs naturally, as opposed to controlled pollination, no effect of selection from human interference

optimum: 1. the most favorable condition for growth and reproduction 2. peak production

organic: 1. made of, derived from, or related to living organisms: Growers of organic cannabis use fertilizers and insect control methods of animal or vegetable origin.



Node

Unaltered rock powders are also considered organic.

osmosis: the equalizing movement of fluids through a semi-permeable membrane, such as in a living cell

outbreeding: breeding between individual cannabis plants that are not closely related

outcross: the process of breeding using individuals outside of the family, population, or group

overload: load to excess: An electrical circuit that uses more than 80 percent of its potential is overloaded. A 20 amp circuit drawing 17 amps is overloaded.

ovule: egg which contains the female genes and is found within the plant ovary: When fertilized, an ovule will grow into a seed.

oxygen: tasteless, colorless, odorless element: Plants need oxygen in the soil in order to grow.

parasite: organism that lives on or in another host organism without benefiting the host: Fungus is a parasite.

passive: hydroponic system that moves the nutrient solution through absorption or capillary action

pathogen: a disease-causing micro-organism, especially bacteria, fungi, and viruses

peat: partially decomposed vegetation (usually moss) with slow decay due to extreme moisture, cold, and acidic conditions

perennial: a plant, such as a tree or shrub, that completes its life cycle over several years

perlite: amendment of sand or volcanic glass expanded by heat, which aerates the soil or growth medium

pH: a scale from 0-14 that measures a growing medium's (or anything's) acid to alkaline balance: a pH of 7 is neutral, lower numbers indicate increasing acidity, and higher numbers increasing alkalinity: Cannabis grows best in a 6.5 to 8 pH range.

pH tester: electronic instrument or chemical used to measure the acid or alkaline balance in soil or water

phenotype: the outward form, characteristic,



Photosynthesis

and appearance of a plant, determined by the interaction of the individual genotype with the environment

phloem: the

food- and water-conducting tissue of vascular plants

phosphor coating: internal fluorescent bulb coating that diffuses light and affects various color outputs

phosphorus (P): one of the macronutrients that promote root and flower growth

photoperiod: the relationship between the length of light and dark in a 24-hour period; affects the growth and maturity of cannabis

photosynthesis: the building of chemical compounds (carbohydrates that plants need for growth) from light energy, water, and CO₂

phototropism: the environmental response movement of a plant part toward or away from a light source

phyllotaxy: the arrangement of leaves on a stem, and the principles that govern such arrangement

phytotron: a completely enclosed indoor area with extensive environmental controls for the experimental growth (and study) of plants

pigment: the substance in paint or anything that absorbs light, producing (reflecting) the same color as the pigment

pistillate: female; having pistils but no functional stamens

pistils: small pair of fuzzy white hairs extending from top of female calyx: Pistils catch pollen and channel it into contact with the ovule for fertilization.

pod, seed: a dry calyx containing a mature or maturing seed

pollen: fine, yellow, dust-like microspores containing male genes

pollen sack: male flower containing pollen

pollination: the transfer of male pollen from

the anther to the stigma of the same or a different flower to fertilize ovules which produce seeds

polyhybrid cross: a hybrid plant crossbred for more than one trait

pot: 1. container for growing medium 2. American slang word for marijuana

potbound: root system that is bound, stifled, or inhibited from normal growth by a too-small container

potassium (K): one of the macronutrients necessary for plant life

potent: capable of wielding strong physiological or chemical effects: marijuana rich in THC that provides a desirable psychoactive effect

power surge: interruption or change in flow of electricity

predatory insect: beneficial insect or parasite that hunts down and devours harmful insects

primordia: belonging to or characteristic of the earliest stage of development of an organism or a part

progeny: one born of, begotten by, or derived from another; an offspring or a descendant: offspring or descendants considered as a group

propagate: 1. sexual propagation: to produce a seed by breeding a male and female plant 2. asexual propagation: to produce a plant by cloning

pruning: trimming branches or parts of plants to strengthen those that remain, or bring shape to the plant

Punnett square: a tool developed by British geneticist, R e g i n a l d Punnett, used by biologists to predict the probability of possible genotypes of offspring



Root bound plant.

PVC (polyvinyl chloride) pipe: plastic pipe that is easy to work with, readily available, and used to transport liquid and air

pyrethrum: natural insecticide made from the blossoms of various chrysanthemums

RH: relative humidity: see humidity, relative

radicle: the part of a plant seedling that develops into a root, the root tip

recovery: hydroponic system that reclaims the nutrient solution and recycles it

rejuvenation: a mature plant, having completed its life cycle (flowering) that is stimulated by a new 18-hour photoperiod, to rejuvenate or produce new vegetative growth

resin glands: tiny pores that secrete resin

retting: to moisten or soak in order to soften and separate the fibers from the woody tissue by partial rotting

root: 1. the underground part of a plant: Roots function to absorb water and nutrients as well as anchor a plant in the ground. 2.



Sea of Green.

to root (start) a cutting or clone

root hormone: root-inducing substance

rootbound: see potbound

roguing: to weed out inferior, diseased, or undesirable plants from a crop, field, or population area

salt: crystalline compound that results from improper pH or toxic build-up of fertilizer: Salt will burn plants, preventing them from absorbing nutrients.

scion: the shoot (containing buds) that is used for grafting

SCROG: screen of green: a growing method which involves training cannabis shoots onto a net, trellis, or chicken wire

scuff: to scrape and roughen the surface: Seeds with a hard outer shell germinate

faster when scuffed.

Seal-a-meal: airtight sealer for plastic baggies used to seal in freshness of pungent marijuana

secondary nutrients: calcium (Ca) and magnesium (Mg). Ca and Mg are considered to be primary nutrients by some sources.

seed: the mature, fertilized ovule of a pistillate plant, containing a protective shell, embryo, and supply of food: A seed will germinate and grow, given heat and moisture.

selfing: to fertilize with pollen from the same flower or plant; self-pollination

senescence: the (declining) growth stage in a plant or plant part from its prime to death

sexual propagation: in plants, the reproduction by means of seed following fertilization

shake: slang term for "Bunk," lower growth, or least potent portion of harvest: small particles of cannabis broken off the main "nug" inside a bag due to rough handling: Many times, shake is flaked or powder-like and used for cooking.

short circuit: condition that results when wires cross and form a circuit. A short circuit will trip breaker switches and blow fuses.

sinsemilla: two Spanish words: sin = without, semilla = seed, combined into one word by Americans: Sinsemilla describes potent marijuana from flowering female cannabis plants kept seedless by preventing pollination in order to promote a high THC content.

soap: 1. cleaning agent 2. wetting agent 3. insecticide: All soap used in horticulture should be biodegradable.

socket: threaded, wired holder for a lightbulb

SOG: Sea of Green: a method of growing tightly spaced cloned plantlets. The clones are flowered almost immediately after rooting for a small yield per plant, but no wasted space.

soiless mix: a growing medium made up of mineral particles such as vermiculite, perlite, sand, pumice, etc.: Organic moss is often a component of soiless mix.

soluble: able to be dissolved in liquid, especially water

solution: 1. a mixture of two or more solids, liquids, or gases, often with water 2. answer to a problem

sponge rock: large pieces of perlite, a light, mineral soil amendment

spore: seed-like offspring of certain bacteria, fungi, algae, and some nonflowering plants

sprout: 1. a shoot of a plant, as from a recently germinated seed 2. small, new growth of leaf or stem

square feet (sq. ft.): length $\times$ width; a measurement of area

stagnant: motionless air or water: for healthy cannabis growth, water must drain and not become stagnant

stamen: the male floral organ, bearing the anther, which produces pollen to fertilize female flowers

staminate: male, pollen-producing flower having stamens but no pistils

sterilize: to make super clean by removing dirt, germs, and bacteria; disinfect pruning tools to avoid spreading disease

stigma: the tip of the flower's pistil, which receives the pollen

stigmatic: the portion of the pistil on which the pollen germinates

stipule: one of a pair of small, leaf-like appendages found at the base of the leaf-stalk of many plants

stomata: small mouth-like or nose-like openings on leaf underside, responsible for transpiration and many other life functions: The millions of stomata must be kept very clean to function properly.

strain: 1. ancestry, lineage, phenotype, a particular type of cannabis having the same characteristics

stress: a physical or chemical factor that causes extra exertion by plants, usually by restricting fluid flow to foliage: A stressed plant will grow poorly.

substrate: the medium on which an organism lives, as soil, soilless mix, rock, etc.

sugar: food product of a plant

sump: a reservoir that receives drainage; a drain or receptacle for hydroponic nutrient solutions used for growing cannabis

super bloom: a common name for fertilizer high in phosphorus and potassium that

promotes flower formation and growth

synthesis: the production of a substance, such as chlorophyll, by uniting light energy, elements, or chemical compounds

taproot: the main or primary root that grows from the seed: Lateral roots will branch off the taproot.

taxonomy: classification of plants and animals according to their family relationships

Teflon tape: tape that is extremely useful to help seal all kinds of threaded pipe joints. I like Teflon tape better than putty.

tepid water: lukewarm 70-80°F (21-27°C)
water: Always use tepid water around plants to facilitate chemical processes and ease shock.

terminal bud: the growth tip of main stem or branch

terpene: hydrocarbons found in essential oils (resins) produced by plants; gives the resin a strong aroma

testa: the hard outer covering of a seed

THC: tetrahydrocannabinol: physiologically active ingredient which is the primary intoxicant in marijuana

THCV: tetrahydrocannabivarinol: a psychoactive chemical found in cannabis

thermostat: a device for regulating temperature: A thermostat may control a heater, furnace, or vent fan.



Terminal bud.

timer: an electrical device for regulating photoperiod, fan, etc.: A timer is a must in all grow rooms.

toxic life: the amount of time a pesticide or fungicide remains active or live

transformer: a device in the ballast that transforms electric current from one voltage to another.

transpire: to give off water vapor and by-products via the stomata on leaves

transplant: to uproot a plant and root ball and replant it in new soil

trellis: a frame of small boards (lattice) that trains or supports plants

trellising: method of restricting plant growth or altering its shape and size by tying plant to lattice work or wire screen

trichome: resin-secreting plant hair

triploid: having three sets of chromosomes within each cell, may contribute to increased vigor

tungsten: a heavy, hard metal with a high melting point that conducts electricity well: Tungsten is used for a filament in tungsten halogen lamps.

ultraviolet: light with very short wavelengths, out of the far blue visible spectrum

variety: distinct strain, phenotype (see strain)

vascular: referring to a plant's circulatory system which carries sap throughout the body of the plant

vector: 1. an organism (as an insect) that transmits disease, a pathogen 2. an organism that transmits genes, a pollinator

vegetative: growth stage in which cannabis rapidly produces new leafy growth and green chlorophyll

vent: an opening such as a window or door that allows the circulation of fresh air

ventilation: circulation of fresh air, fundamental to a healthy indoor garden: An exhaust fan creates ventilation.

vermiculite: mica processed and expanded by heat: Vermiculite is a soil amendment and medium for rooting cuttings.

vitamin B1: vitamin that is absorbed by tender root hairs, easing transplant wilt and shock

weed: 1. slang word for marijuana 2. any undesirable plant: One person's weed is another person's flower!

wetting agent: a compound that reduces the droplet size and lowers the surface tension of the water, making it wetter: Liquid concentrate dish soap is a good wetting agent if it is biodegradable.

whorl: where three or more leaves or petals arise from the same point and form a circle around it

whorled phyllotaxy: three or more leaves or branches located at each node along the branches and stems: People often confuse the term whorled phyllotaxy with the condition, triploidy (a chromosomal anomaly).

wick: the part of a passive watering system the nutrient passes up to be absorbed by the medium and roots: A passive hydroponic system uses a wick suspended in the nutrient solution.

wilt: 1. to become limp from lack of water 2. plant disease/disorder

wire ties: paper-coated wire ties are excellent for tying down or training plants

xylem: vascular tissue that transports water and minerals from the roots throughout the stems and leaves

Zero Zero (hash): top-quality, first-sieve hash



Index

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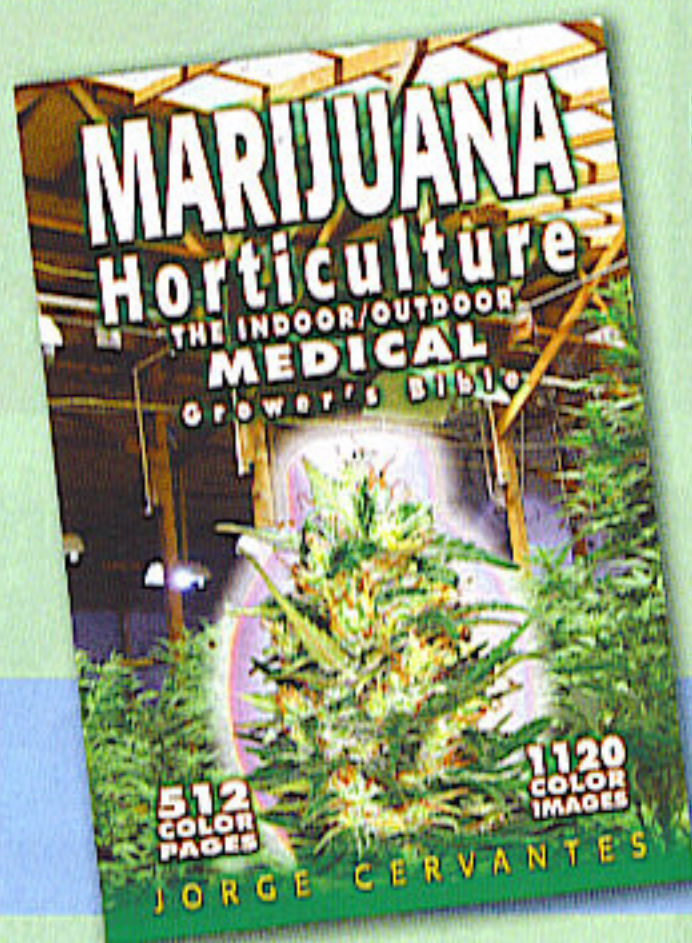
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Jorge writes a monthly column, *Jorge's Rx*, and regular feature articles in *High Times* magazine. He also writes a regular column in all editions (Dutch, English, French, Italian and Spanish) of *Soft Secrets* magazines. His work has also appeared in numerous magazines from Japan to Germany. Below are some of the magazines in which you can find Jorge's work.



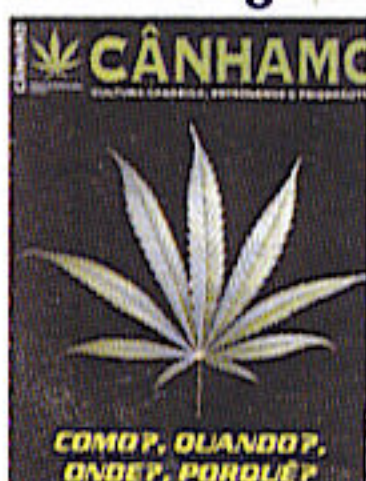
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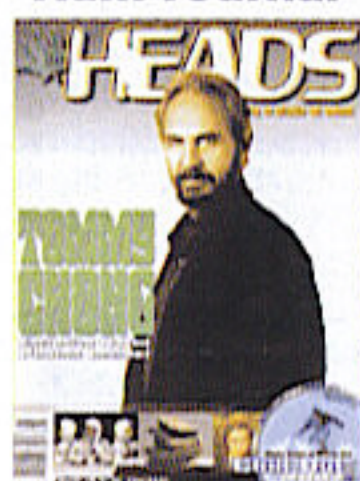
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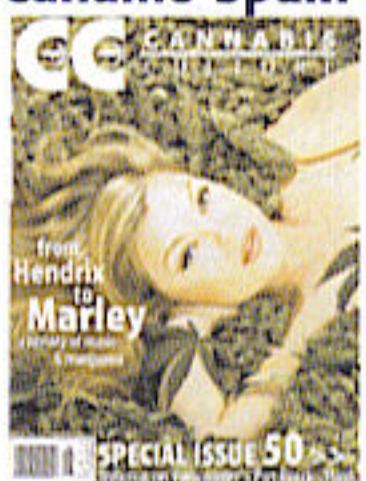
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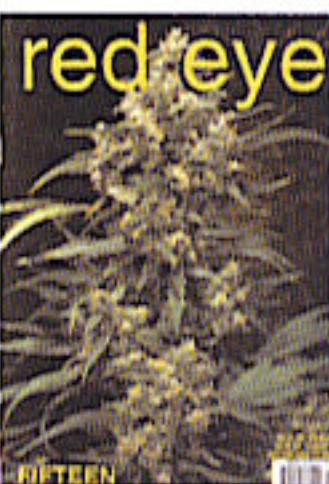
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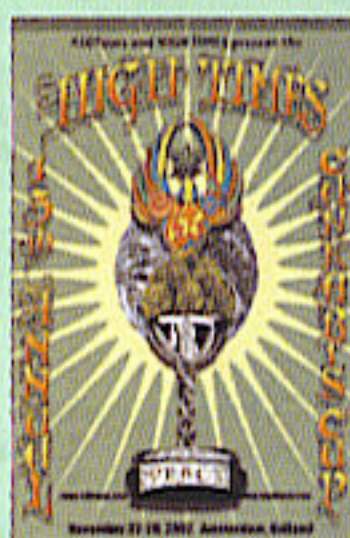


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Jorge Cervantes is a regular speaker at the following Cannabis Trade Fairs. He also gives grow seminars throughout Europe.

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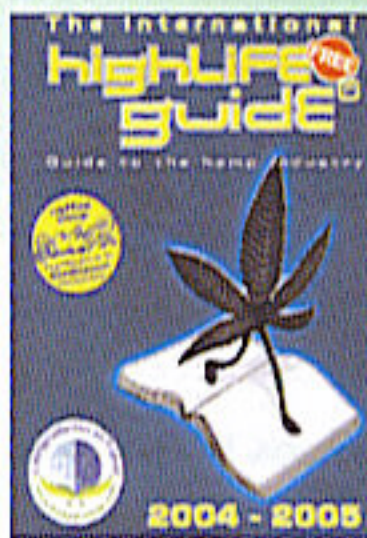
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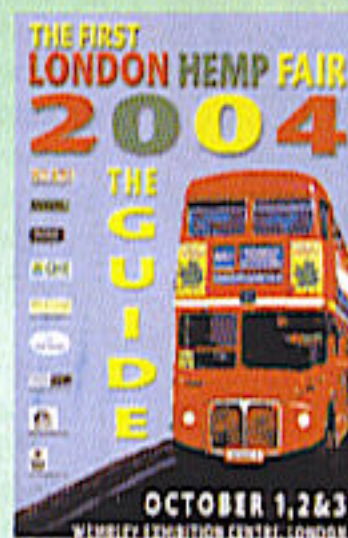
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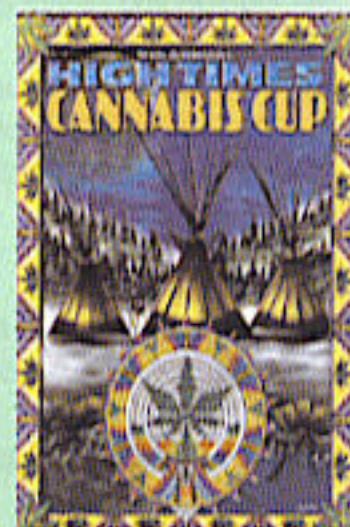
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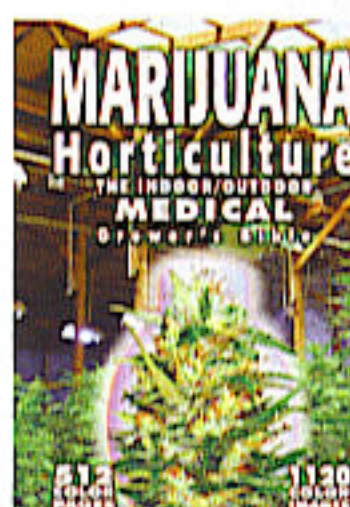
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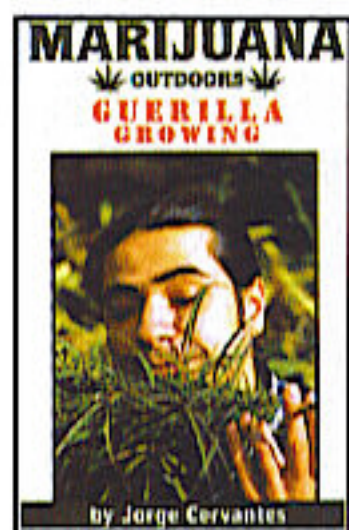


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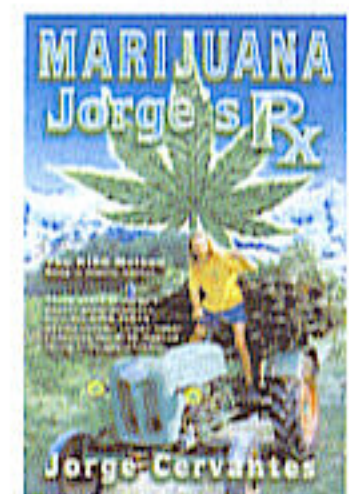


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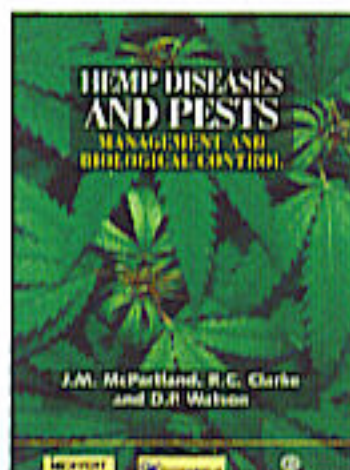


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